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Review of Upper Station Sockeye Salmon Management and Research

by

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and

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May 2015

Alaska Department of Fish and Game

Divisions of Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

Sockeye salmon production from the South Olga lakes, also known as Upper Station, in the Alitak Bay District of the Kodiak Management Area, decreased in recent years. The department initiated a review of Upper Station sockeye salmon historical data and fishery management practices to better understand the conditions that have influenced this decline and to identify what data gaps exist. This Regional Information Report presents the memorandum crafted from the review of historical Upper Station management and research data. The memorandum identifies that healthy rearing conditions persist in Upper Olga Lake, however, data gaps exist regarding stock identification of catch and escapement, useable spawning habitat, usage of Lower Olga Lake as rearing habitat, smolt condition at age, juvenile sockeye salmon diets, and quality of nearshore rearing environments.

Key words: Upper Station, South Olga lakes, sockeye salmon, escapement, Alitak Bay District, zooplankton, smolt, research, memorandum, age, size.

MEMORANDUM

State of Alaska

Department of Fish and Game
Westward Region Office

TO: Nicholas H. Sagalkin
Regional Finfish Research Supervisor
Division of Commercial Fisheries
Region IV- Kodiak

DATE: November 21, 2013

CC: Honnold, Wadle

PHONE NO: 907-486-1848

FROM: Heather Finkle and Mary Loewen
Regional Finfish Research Biologists
Division of Commercial Fisheries
Region IV- Kodiak

SUBJECT: Review of Upper Station sockeye salmon management and research

Sockeye salmon production from the South Olga lakes, also referred to as Upper Station in the Alitak Bay District (ABD) of the Kodiak Management Area (KMA), has decreased in recent years. The department initiated a review of historical data and fishery management practices of Upper Station sockeye salmon to better understand the conditions that have influenced this decline and identify what data gaps exist. This memorandum serves to present results from the review.

DESCRIPTION OF STUDY AREA

The South Olga lakes system, also referred to as Upper Station, is composed of two lakes located on the southern end of Kodiak Island and supports one of the largest sockeye salmon runs in the Kodiak Archipelago (Jackson et al. 2012). While the lakes are labeled “Upper Station” on some maps, this name actually refers to a former U.S. Fish and Wildlife research station that was located at the outlet of the lower lake and now refers to the commercial fisheries management weir. This memorandum uses the convention of referring to the weir site and its escapement as Upper Station, and using Upper or Lower Olga Lake to refer to the lakes.

The Upper Station system drains into upper Olga Bay (57° 04 N; 154° 15 W) via South Olga Creek. Upper Olga Lake refers to the most upstream lake, and Lower Olga Lake refers to the downstream lake nearest to Olga Bay (Figure 1). There is an additional unnamed small lake (~ 1.0 km long) that feeds into Upper Olga Lake. Upper Olga Lake is 6.0 km long, up to 2.0 km wide, and has a surface area of 7.9×10^6 m^3 (Honnold 1993; Schrof et al. 2000). The mean depth of Upper Olga Lake is 26.2 m and it is classified as oligotrophic (Finkle 2012; Schrof et al. 2000). Lower Olga Lake is 4.0 km long, up to 1.6 km wide, and has a surface area of 4.4×10^6 m^3 (Schrof et al. 2000). Lower Olga Lake has a mean depth of 2.0 m and is considered mesotrophic (Honnold 1993; Figure 1).

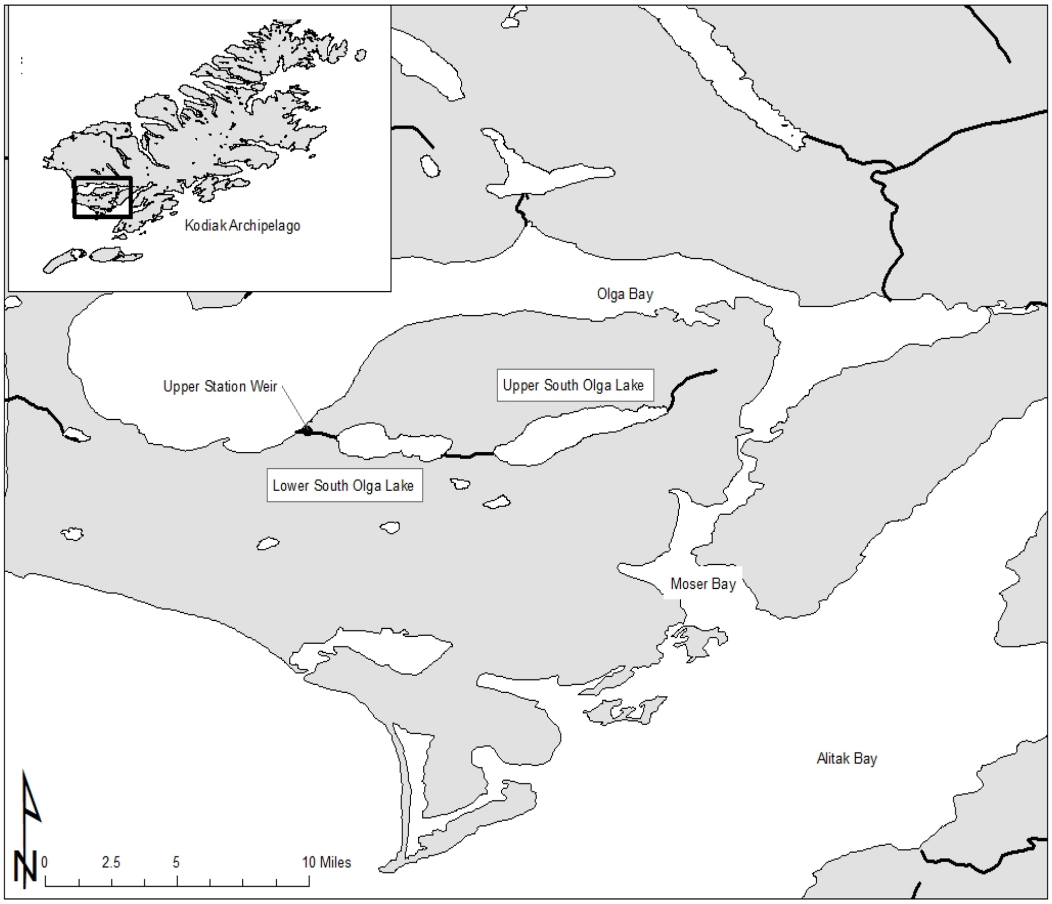

Figure 1.–Map of Alitak Bay and South Olga Lakes

REVIEW OF ESCAPEMENT GOALS

Two temporally distinct sockeye salmon runs return to Upper Station (Barrett and Nelson 1994; Gomez-Uchida et al. 2012; Sagalkin unpublished memo 2002). The early run returns from late May through mid July; the late run returns from mid July through September. Sockeye salmon escapements at Upper Station have been enumerated through the weir annually for most years since 1928. Since 1988, sockeye salmon escapement through July 15 is attributed to the early run and after July 15 to the late run. Run reconstructions based on escapement and scale pattern analysis are available for the early run beginning in 1969 and for the late run in 1970.

Prior to 1978, no escapement goals were established for the Upper Station system. From 1978 to 1982, the Upper Station total sockeye salmon stock was managed for one escapement goal, with a range of 100,000 to 180,000 fish (Table 1). The majority of fishing pressure had traditionally focused on late-season salmon and reflecting this, the escapement goal was divided into monthly increments from July through September with August further subdivided into weekly objectives (July 30,000 sockeye salmon, August 130,000 sockeye salmon, September 20,000 sockeye salmon; Nelson and Lloyd 2001).

Table 1.–Timeline of changes to Upper Station sockeye salmon escapement goals and relevant events.

Year	Action
1978	First escapement goal of 100,000 to 180,000 fish for total run recommended by Chair of the Board of Fisheries and used in preseason management plans: July: 30,000 fish, August: 130,000 to 175,000 fish, September: 20,000 fish.
1977-1979	High returns from 1974 escapement of 286,553 sockeye salmon
1983	Escapement goals increased to 150,000 to 250,000 sockeye salmon and extended into June with 50,000 fish allocated for fishing through July.
1988	Formal early- and late-run goals established: Early-run SEG 50,000-75,000 fish; Late-run SEG 150,000-200,000 fish.
1992-1999	No management tools in place to manage for Upper Station early run escapement goals; ER did not meet lower bound of SEG 1992-1995, 1997-1999.
1999	ADF&G adds Upper Station into ABDMP to ensure escapements can be targeted and allow fisheries in Inner and Outer Upper Station areas.
	BOF implements Upper Station ER OEG of 25,000 to faciliate harvests of Frazer Lake sockeye salmon.
2001	Late-run escapement fails to meet lower bound of SEG.
2002	Poor early and late runs result in near-total lack of fishing time in ABD.
2004	ER SEG changed to 30,000-60,000 fish (OEG in place); LR SEG changed to BEG of 120,000-265,000 fish.
2010	ER SEG changed to BEG of 43,000-93,000 (OEG in place)
2011	LR fails to meet lower bound of escapement goal.

The unexpectedly high escapement of 286,553 sockeye salmon in 1974 resulted in strong returns during 1977, 1978, and 1979. Fisheries closures between 1971 and 1977 to protect Karluk early-run sockeye salmon and the newly established Frazer sockeye salmon run concurrently allowed development of the early run.

In 1983, the total escapement goal was increased to 150,000 to 250,000 fish, which remained in place through 1987 (Table 1; Nelson and Lloyd 2001; Sagalkin unpublished memo). The escapement goal was also extended into June with 50,000 fish for June and July combined. This allocated 20,000 fish for June, as a 30,000 fish goal existed for July. The change in escapement goal timing was largely in response to the increased interest in harvesting the early portion of Upper Station sockeye salmon run, which necessitated an escapement goal for that period. At this time, the August escapement objective also increased from 130,000 fish to 175,000 fish, and was broken down into weekly increments with the largest escapement objective in week three (Table 1).

The Alitak Bay District Management Plan (ABDMP; Keyse 2013) was adopted into regulation in 1987. In keeping with past management practices, the ABDMP reflected that early season sockeye salmon returns to Frazer Lake would determine fishing time in the traditional harvest areas and only the Inner and Outer Upper Station sections were managed based on the Upper Station early run. The management plan did not utilize closures to achieve Upper Station sockeye salmon escapement objectives during Frazer-targeted fisheries. Late-run sockeye salmon management emphasis began on July 16 and focused either on late-run Upper Station sockeye or pink salmon runs depending on even-or odd-year cycles and section.

In 1988, the Upper Station escapement goal was formally divided into early- and late-run goals, and the early-run Sustainable Escapement Goal (SEG) was established as 50,000 to 75,000 sockeye salmon through July 15 (Nelson and Lloyd 2001). The late-run SEG was established as 150,000 to 200,000 fish from July 16 to mid September (Table 1; Nelson and Lloyd 2001).

Between 1989 and 1999, both Frazer Lake and late-run Upper Station escapements met, and often exceeded, their escapement goals (140,000-200,000 and 150,000-200,000 respectively). Their harvest levels were commensurately high for this time period as well. Early-run escapements, however, failed to meet their goal for six of those 11 years and harvests were relatively lower (Nemeth et al. 2010). During this time when the Upper Station early run was weak but Frazer Lake escapements were strong, "mop-up" fisheries in Olga Bay were necessary to control escapements through Dog Salmon weir or risk exceeding the Frazer escapement goal.

During the 1999 Board of Fisheries (BOF) meeting, the BOF amended the ABDMP to provide fishing time to address staying with the bounds of the Frazer Lake escapement goal yet provide adequate escapement for the Upper Station early run. The amendment created a "trigger point" to allow fishing in the normally closed waters of Olga Bay (Proposal #114, 1998 Alaska Board of Fisheries Meeting) if excessive escapement to Frazer Lake was projected.

Given the mixed stock fishery in the ABD and the greater production potential of the Frazer Lake run, the BOF established an Optimum Escapement Goal (OEG) of 25,000 fish for the early run of Upper Station sockeye salmon. This OEG was intended to sustain the early-run Upper Station escapement and harvest levels while directing the June fisheries on the larger Frazer Lake sockeye salmon run. This allocation ensured that the management practices of the past would not change and the June Alitak District fishery would still be managed prior to July 16 based on the dominate Frazer Lake stock. Escapements at the OEG level provided for escapement and harvest in the past (Appendix A2), and the OEG was corroborated by an unpublished sustainability analysis conducted by the ADF&G in 2000 (Nelson and Lloyd 2001; unpublished Alaska Department of Fish and Game manuscript obtained from Nick Sagalkin, Kodiak, Alaska).

In 2004, the department recommended lowering the early-run SEG to 30,000 to 60,000 fish (Nelson et al. 2005). The late-run SEG was widened and changed to a Biological Escapement Goal (BEG) based on spawner-recruit analysis. Coinciding with the changes to Upper Station, the Frazer Lake escapement goal was lowered from a BEG of 140,000 to 200,000 fish to its current goal of 70,000 to 170,000 fish. No change was recommended to either Upper Station goal in 2007, but the 2010 review recommended changing the early-run escapement goal to a BEG of 43,000 to 93,000 sockeye salmon based on Ricker spawner-recruit analysis. No change was recommended for the late-run escapement goal in 2010 (Nemeth et al. 2010).

Upper Station early-run escapements in the past three years have been some of the lowest on record and have not met the BEG, although they have met the OEG (Figure 2). With the exception of 2001 and 2011, the late run has met the lower end of the late-run escapement goal each year since 2000 (Figure 2). The 2010 escapement goal report acknowledged the downward production trend for the Upper Station system that began in the 1980s and indicated that an escapement level greater than 25,000 sockeye salmon could increase early-run productivity (Nemeth et al. 2010). The most recent escapement goal review, begun in 2013, recommended no change to the early-run BEG of 43,000 to 93,000 fish, and no change to the late-run BEG of 120,000 to 265,000 fish.

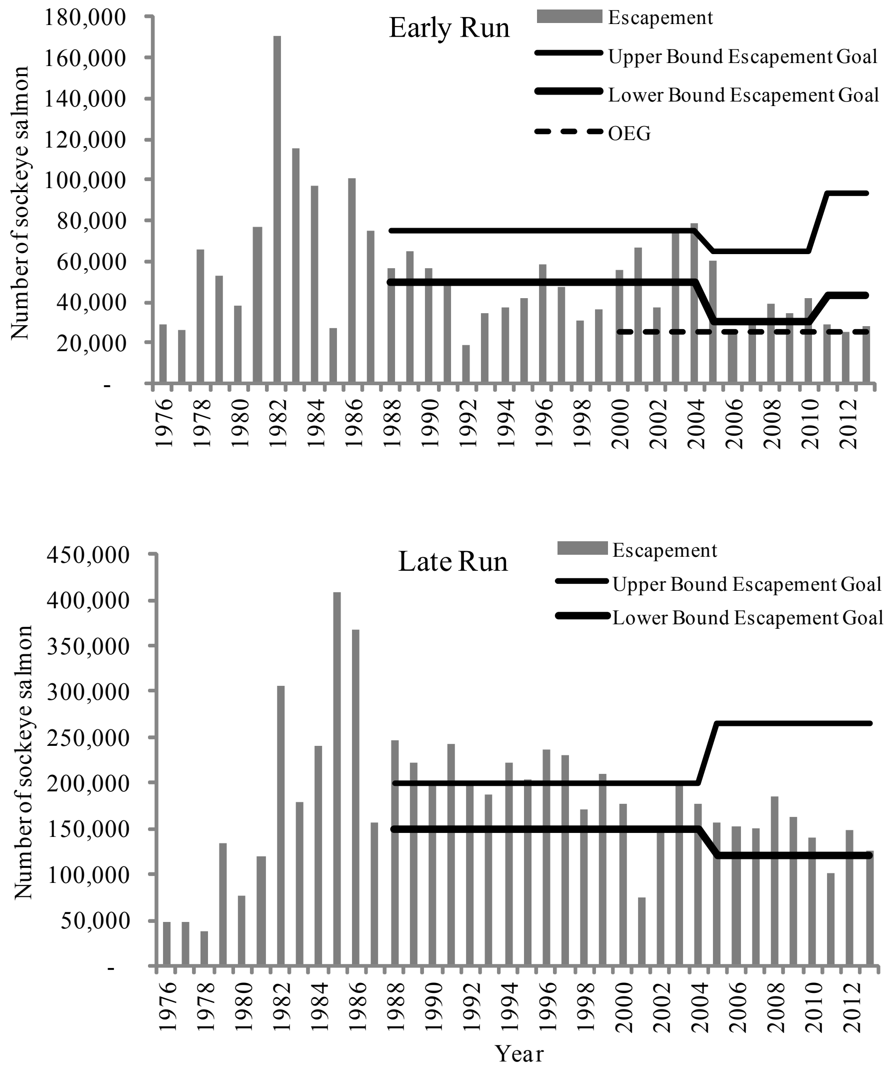

Figure 2.–Annual Upper Station escapement of sockeye salmon by run from 1976 to 2013.

REVIEW OF COMMERCIAL HARVEST AND ESCAPEMENT TRENDS:

Although escapements have generally met the lower bounds of their goals, the overall harvest and total return numbers, return-per-spawner (R/S) ratios, and number of commercial fishery openings for each run have declined in recent years and reflect the overall downward production trend of Upper Station sockeye salmon (Figure 3; Appendices A1-A3).

Early-run sockeye salmon escapements have met their SEG or BEG 14 of the 25 years since 1988 and have met the OEG in all years but 2006. Early-run harvests between 1986 and 1996 were some of the largest on record, with an average estimated harvest of 90,436 sockeye salmon (Table 2, Appendix A2). Early-run catches in 2006 and 2007, however, were below 10,000 sockeye salmon. The most-recent three year average harvest (2010-2013) was 29,025 sockeye salmon. Brood years 2001 through 2003 yielded especially poor returns, with 0.7 R/S (less than the replacement value of 1.0 R/S). The average R/S of the most recent three years of fully-recruited returns is 1.5 R/S.

Table 2.–Averaged escapement and catch of sockeye salmon apportioned to Upper Station, as well as 1986-1996 high productivity period and 2013 Upper Station returns.

	Early Run			Late Run			Combined Runs
Average	Escapement	Catch	Run	Escapement	Catch	Run	Total Run
1986-1996[a]	54,073	90,436	144,509	225,641	494,512	720,153	864,662
20-year (1994-2013)	44,069	62,292	106,361	168,821	187,932	356,753	463,114
10-year (2004-2013)	39,313	50,685	89,998	150,089	122,285	272,374	362,372
5-year (2009-2013)	31,721	29,361	61,081	135,933	83,517	219,450	280,532
3-year (2011-2013)	27,319	29,025	56,345	125,597	55,621	181,218	237,563
2013	27,712	29,502	57,214	125,573	33,656	159,229	216,443

[a] This includes the 1988 run of over 1 million late-run sockeye salmon, with a harvest of over 754 thousand fish.

The late run is greater in magnitude than the early run, and is considered less variable, although harvests have decreased in recent years (Figure 3). The Upper Station late run has met the lower bound of the escapement goal range each year (with the exceptions of 2001 and 2011) since 1990 (Figure 2). However, in 2001, late-run escapement did not meet the lower bound of the escapement goal, and the run was the smallest on record. Low returns for both early and late Upper Station and Frazer runs in 2002 resulted in a total lack of fishing time in the traditional gillnet only areas of the ABD. Similar to the early run, the mid 1980s and 1990s were a period of high productivity, with an average estimated harvest of 494,512 sockeye salmon between 1986 and 1996. Much of that harvest was driven by a huge run in 1988 of over 1 million sockeye salmon, with an associated estimated harvest of 754,836 sockeye salmon (Figure 3). The most recent three years (2010-2012) have had the lowest average estimated catches of 65,509 sockeye salmon. Relative to the ABDMP, total production gradually declined over time following the large return in 1986 ($p<0.001$, $R^2=0.54$), which was subsequent to the 1983 goal increase and first upper Olga Bay mop-up fishery. The declining trend continued through 2000 following the implementation of the OEG in 1999, however, the rate of decline slowed substantially after 2000.

Early-run escapement poorly describes the variability of early-run returns (brood years 1980-2006, $p=0.10$, $R^2=0.11$). Late-run escapement has a significant ($p=0.01$) positive relationship with early-run returns, but the relationship is weak ($R^2=0.24$) and violates model assumptions. Thus, consideration should also be given to environmental factors and the implementation and changes to escapement goals for describing early run variability. For the Upper Station late run, a significant positive relationship exists between the late-run escapement and late-run returns (brood years 1980-2006, $p<0.001$, $R^2=0.47$).

Recent R/S values for the Upper Station early run have been variable with escapements from 2001 to 2003 yielding returns below the replacement level (1.0). Whether this is because of less favorable marine or freshwater conditions is uncertain. The early run exhibits a cyclical pattern of increased R/S approximately every six to eight years (Figure 4). In the past, the peak of the cycle has resulted in a R/S as high as 8.0. The most recent peak in the cycle should have occurred in returns from escapements in 2006, yet the R/S was 2.0. Returns from the 2007 early-run escapement (31,895 sockeye salmon) will be completed in the 2014 fishing season; it is unlikely that returns of the 3.3 and 2.4 age classes will raise the 2007 R/S higher than that of brood year 2006. Between 1976 and 1982, the R/S for late-run sockeye salmon ranged from 4.0 to 16.1 (Figure 4). Fully recruited late-run brood years from 1983 to 2007 have an average R/S of 2.1. The most recent three years of fully recruited late-run returns have a mean R/S of 1.7 (Appendices A2 and A3). The number of landings, as well as the number of days with commercial fishing openings for setnet gear type, has decreased since the 1990's.

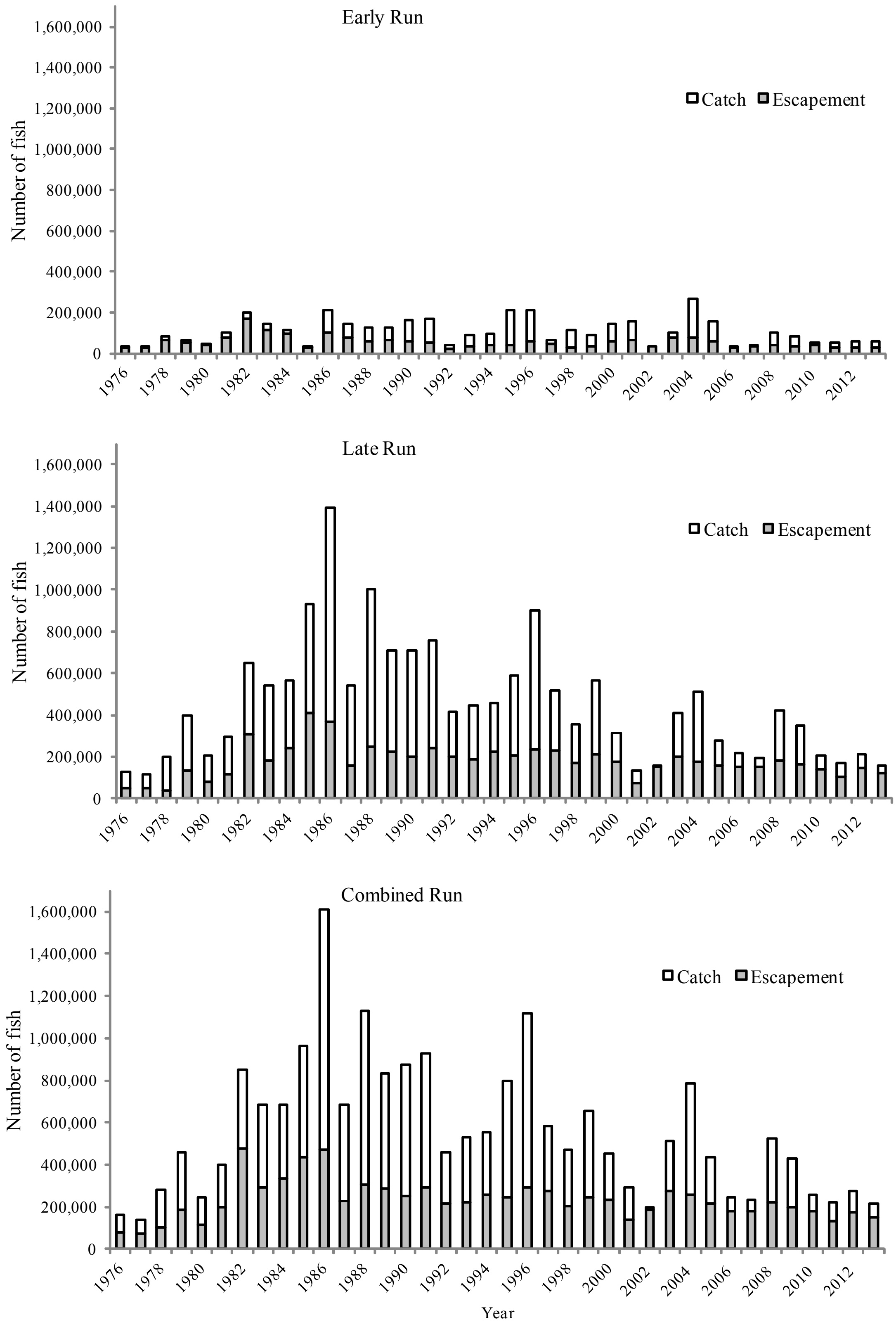

Figure 3.–Annual catch and escapement of sockeye salmon apportioned to Upper Station 1976-2013.

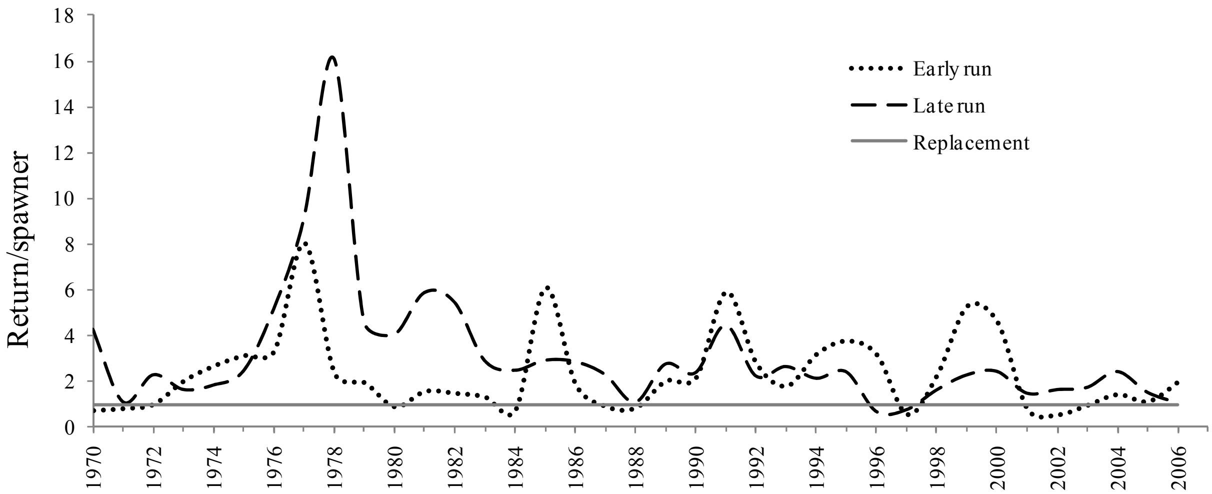

Figure 4.–Return per spawner of Upper Station sockeye salmon, 1970 through 2006.

REVIEW OF RESEARCH AND OTHER WORK CONDUCTED IN THE SOUTH OLGA LAKES SYSTEM

Most research has taken place at Upper Olga Lake and has included limnological sampling, hydroacoustic surveys, and townetting. Limited limnological and juvenile sampling has been conducted at the lower lake, which has been suggested to be a spring and early-summer rearing area for outmigrating freshwater-age-0 sockeye salmon juveniles. Grab sampling of outmigrating sockeye salmon was performed in 2013 at the weir site to collect age, weight, and length data.

USE AS BROODSTOCK

Upper Station late run has served as a broodstock source for Spiridon Lake between 1989 and 1996, for Jennifer Lake in 1993, 1994, and 1996, and for either Little Kitoi Bay or Lake from 1988 to 1991 and 1993 to 1995 (Honnold et al. 1998). Between 120 and 6,800 sockeye salmon were used for broodstock in any year (Table 3).

Table 3.–Proportion of late-run Upper Station sockeye salmon escapement used as broodstock from 1988 to 1996.

Year	Escapement	No. Brood Stock	Spawners	% of Escapement
1988	247,647	120	247,527	0.05%
1989	221,706	3,000	218,706	1.35%
1990	198,287	3,700	194,587	1.87%
1991	242,860	3,800	239,060	1.56%
1992	199,067	6,816	192,251	3.42%
1993	187,229	5,551	181,678	2.96%
1994	221,675	120	221,555	0.05%
1995	203,659	3,668	199,991	1.80%
1996	235,727	4,810	230,917	2.04%

TAGGING AND GENETICS SAMPLING

Tagging studies to determine run timing and catch proportions of Upper Station sockeye salmon have been conducted since the late 1950s (Appendix D). The most recent work on stock separation is a 1981 tagging study, summarized by Tyler et al. (1986). The 1981 study is of particular interest to Alitak Bay fishermen because 57% of the released tagged fish were recovered in Olga Bay. It should be noted that in 1981, the Karluk sockeye salmon escapement was low (222,206 fish for the early- and late-run combined) while the Frazer escapement was very high (377,716 fish). Additionally, the study speculated that there was deliberate under-reporting of tags recovered in the Kodiak seine fishery, while tags recovered in the set gillnet fishery were reported because of the desire of set netters to demonstrate the terminal fishery nature of their harvests.

Another tagging study in 1984 sought to obtain information on the migration characteristics of early-run Upper Station and Frazer sockeye salmon in lower Olga Bay and Moser Bay. In that study, 1,113 tags were released between June 20 and June 30. During the tag recovery period (June 21 to July 28) there was no commercial fishing. Over half of the tags were recovered, and department staff weighted the recoveries to account for differential run strength in that year. Barrett and Nelson (1994) estimated run timing of sockeye salmon along the coast of Kodiak Island, indicated that Upper Station and Karluk share similar peaks to their early runs in mid June and late runs in August.

Genetic samples have been collected from Upper Station sockeye salmon as part of the Western Alaska Salmon Stock Identification project (WASSIP; Baker et al. 2012), as well as part the Southwest Kodiak Genetics project (M. B. Foster, Commercial Fisheries Biologist, ADF&G, Kodiak, personal communication). Gomez-Uchida et al. (2012) analyzed Upper Station early- and late- run sockeye salmon as part of a study of genetic drift among populations. No genetic information has been collected for use in stock separation of harvests in the ABD.

SPAWNING HABITAT STUDIES

South Olga lakes were surveyed in 1999 and 2000 to quantify the amount of useable spawning habitat and to identify whether the early and late runs used different spawning locations (Honnold et al. 1996).

Lower Olga Lake was surveyed for spawning activity in July 1999 using a boat. Foot and boat surveys were conducted on Upper Olga Lake in October 1999 and August 2000. An additional aerial survey was performed July 14, 2000 to identify spawning locations in both Upper Olga and Lower Olga lakes. Early-run and late-run spawners were differentiated based on timing of the surveys. Fish observed in July and August on spawning grounds were assigned to the early run and fish observed in October were assumed to be late run fish.

Spawning locations used in August and July generally were not being used in October and vice versa. The early sockeye salmon run was observed using tributaries to Upper Olga Lake and some shoals immediately adjacent to tributary creeks while late-run spawners were observed using shoals and the stream between the two lakes. No sockeye salmon spawning activity was observed in Lower Olga Lake.

The majority of tributary spawning habitat was classified as fair to poor (Table 4). Most of the stream habitat was listed as “high gradient” and as having “poor substrate” (2004 unpublished data Nick Sagalkin, Alaska Department of Fish & Game, Kodiak, Alaska). A tributary off of the west side creek was the one exception.

Table 4.–Spawning Habitat survey results from 1999 and 2000.

Location	No. of Spawners in Habitat Category				
Upper Lake	Excellent	Good	Fair	Poor	Total
East Creek	0	239	840	322	1,402
North Creek	0	0	3,620	4,661	8,281
West Creek	3,856	n.a.	n.a	n.a.	3,855
West Creek tributary	5,172	n.a.	n.a	n.a.	6,070
Tributary Mouths	400				400
Total Tributary Habitat[a]	9,428	239	4,460	4,983	20,008
Lower Lake					
Outlet Shoals					128,000
SW Shoals					230,000
SE Shoals					0
NW Shoals					0
NE Shoals					140,000
East Shoals					91,000
Outlet					37,918
Shoal Habitat[a]					589,000
Shoal + Outlet Habitat					626,918
Total Spawning Habitat					646,926

[a] Through spawning surveys it was determined that the early sockeye salmon run primarily uses tributary habitat and the late run uses shoal habitat and the outlet between the two lakes.

Spawning habitat evaluation assumes that the amount of habitat available for returning adults to spawn is the most limiting factor for salmon production. While spawning habitat may be limiting in some systems, it is difficult to quantify. However, high gradient streams, such as those recorded as early-run spawning habitat, may be prone to redd scour. Therefore, the success of the early run may be correlated to environmental conditions during incubation; years with winter high-water events may lead to poor future returns. Although the stream between the two lakes where late run sockeye salmon were observed spawning was better redd habitat, this area could be space-limited, hindering egg and alevin survival.

SMOLT AND JUVENILE WORK

Smolt enumeration projects were operated in 1990 through 1993 using a Canadian fan trap with a lead located 1.2 km downstream of the Lower Olga Lake (Barrett et al. 1993). Grab samples of sockeye salmon juveniles were also collected in 1988, 1989, 2003, and 2013 (Table 5). Beach seining was conducted in Lower Olga Lake as part of habitat studies in 1991, and townetting in Upper Olga Lake took place in 1991 and 1992 (Honnold 1993).

Table 5.–Historical freshwater age classes of Upper Station sockeye salmon smolt by location.

Year	Sample Date	Location	*n*	Age 0	Age 1	Age 2	Age 3
1988	5/27	Lower Olga Lake	212	0%	58%	39%	2%
1989	7/16	Lower Olga Lake	190	100%	0%	0%	0%
1990	5/20 - 7/30	Olga Creek	4,395	34%	14%	50%	2%
1991	5/11 - 8/4	Olga Creek	3,317	49%	20%	29%	2%
1992	5/5 - 7/31	Olga Creek	4,139	44%	12%	44%	0%
1993	5/10 - 8/6	Olga Creek	4,305	54%	26%	20%	1%
2003	6/13	Olga Creek	55	0%	7%	89%	4%
2013	5/29-7/29	Olga Creek	607	11%	26%	60%	2%

Population estimates of roughly 2.4 to 7.4 million outmigrating sockeye salmon smolt from 1990 through 1993 were made using mark-recapture techniques (Tables 6 and 7; Barrett et al. 1993). Approximately 350 smolt were sampled per week for age, weight, length, and condition factor.

Table 6.–Estimated age class proportions of the sockeye salmon smolt outmigration from 1990 through 1993.

Year	Number of Smolt by Freshwater Age				Total
	Age 0	Age 1	Age 2	Age 3	
1990	5,511,473	241,181	1,591,424	58,682	7,402,760
1991	1,959,424	224,621	245,673	15,388	2,445,106
1992	1,950,244	80,238	362,990	1,444	2,394,916
1993	2,528,937	568,342	354,833	9,946	3,462,058

Table 7.–Population estimates of outmigrating sockeye salmon smolt from South Olga Lakes 1990-1993.

Brood Year	Escape- ment	Smolt Produced by Freshwater Age				Total Smolt	Smolt/ Spawner	Adult Returns by Freshwater Age				Total return	R/S	Marine Survival
		Age 0	Age 1	Age 2	Age 3			Age 0	Age 1	Age 2	Age 3			
1986	468,734				58,682									
1987	231,021			1,591,424	15,388	1,606,812								
1988	304,371		241,181	245,673	1,444	488,298	1.6	658,846	256,482	209,663	2,112	1,127,103	3.7	
1989	286,288	5,511,473	224,621	362,990	9,946	6,109,030	21.3	385,090	68,206	377,511	217	831,024	2.9	14%
1990	254,446	1,959,424	80,238	354,833		2,394,495	9.4	164,979	391,191	311,148	6,243	873,561	3.4	36%
1991	292,886	1,950,244	568,342			2,518,586	8.6	125,160	167,808	627,256	6,893	927,117	3.2	37%
1992	218,143	2,528,937						198,902	95,991	163,233	2,010	460,136	2.1	
1993	222,081							156,586	170,202	187,637	17,935	532,360	2.4	
1994								173,231	101,944	274,338	2,720	552,233		
1995														

Data from the smolt studies show the majority of the emigrating populations were made up of freshwater-age-0 smolt (Table 6). Based on scale pattern analysis of adult returns, freshwater-age-0 smolt belong only to the late-run, and no population distinction can be made between any of the other age classes (Roche 1992). A corroborating observation by Schrof et al. (2000) noted that scales collected from adults during egg takes at the outlet of Upper Olga Lake in 1988, 1989, and 1994 indicated that a high proportion of the sockeye salmon spawning at that location outmigrated as freshwater-age-0 fish.

The decline in the estimated number of outmigrating freshwater-age-0 smolt from 1990 to 1991 was notable (Table 6). The May 1-m water temperature of Upper Olga Lake was warmer in 1990 (5.3°C) compared to 1991 through 1993 (3.5°C), perhaps contributing to the larger number of outmigrating freshwater-age-0 sockeye salmon in that year.

In general, older age classes outmigrated earlier in the season than younger fish, with freshwater-age-0 smolt typically outmigrating in July and August, whereas other age classes typically outmigrated between late May and early July (Figure 5 and Appendix C1). This timing is typical of sockeye salmon systems (Barnaby 1944).

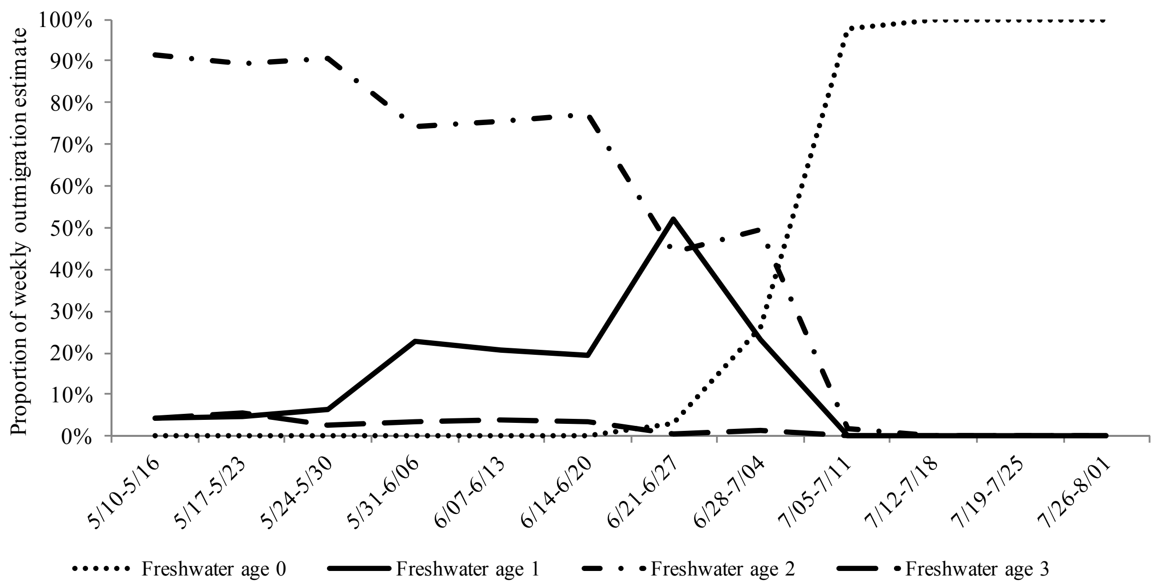

Figure 5.–Outmigration timing by age class, averaged from 1990 to 1993.

No significant differences in mean size (mm) across years within an age class were apparent in outmigrating sockeye smolt sampled from South Olga lakes, except that freshwater-age-1 fish in 2003 and freshwater-age-2 fish in 1993 were larger than the same age classes in other years (Table 8). Weight was not recorded for dipnetted fish in 2003. In general, freshwater-age-0 and -age-1 smolt sampled in 2013 were smaller by age class than fish sampled during the smolt project in the early 1990s, although freshwater-age-2 and -3 smolt were larger compared to previous years.

Analysis of scale patterns from samples collected in 2013 indicated many freshwater-age-1 and freshwater-age-2 smolt displayed signs of poor first-year freshwater growth.

Table 8.–Biological characteristics of outmigrating juvenile sockeye salmon by freshwater age caught in the South Olga Lakes system.

Sampling Year	Age 0			Age 1			Age 2			Age 3		
	n	Length (mm)	Weight (g)	*n*	Length (mm)	Weight (g)	*n*	Length (mm)	Weight (g)	*n*	Length (mm)	Weight (g)
1988[a]	2	61.0	2.7	246	88	6.7	166	108	12.7	10	143	34.1
1989[b]	182	47.0	0.8									
1990	939	54.5	1.5	325	81	4.9	1,539	100	8.3	74	110	11.1
1991	1,622	59.3	2.0	658	94	7.1	947	102	9.3	72	115	12.8
1992	1,813	57.5	1.8	477	94	7.9	1,841	103	10.1	8	113	13.6
1993	2,311	60.5	2.1	1,113	92	6.3	853	111	11.7	27	120	14.9
2003[c]				4	102	-	49	103		2	119	
2013[d]	69	53.7	1.4	160	74	4.3	365	110	11.3	13	127	17.9

[a] Grab samples from outlet of Lower Olga Lake late May.
[b] Grab samples beach seined from Lower Olga Lake mid-July.
[c] Grab samples dipnetted from river in early June.
[d] Grab samples dipnetted or caught using a fyke net from river in early June through late July.

HYDROACOUSTICS AND TOWNETTING

In September 1990 and May and October of 1991, hydroacoustic and townetting surveys were conducted in Upper Olga Lake. Fall population estimates varied substantially between 1990 and 1991 (Table 9) and were lower than estimates from the smolt projects (Tables 6 and 7; Barrett 1992; Honnold 1993). Likely problems were differential net avoidance during townetting (compared to hydroacoustics, as reflected by CPUE; Table 10) and the distribution of fish in unsurveyable areas of the lake. In 1992, no hydroacoustic surveys were conducted, but townetting did occur in September to provide size and age structure information (Table 11).

Table 9.–Results from hydroacoustic surveys of Upper Olga Lake.

	Total Fish Estimates			Sockeye Salmon Estimates			Sockeye Salmon Composition
		95% C. I.			95% C. I.		
Date	Number	Low	High	Number	Low	High	(%)
28-Sep-90	3,843,823	3,376,317	4,311,329	1,172,366	1,029,643	1,315,089	30.5
4-Oct-91	3,987,459	3,431,754	4,543,164	386,784	333,009	440,558	9.7

Table 10.–Catch results from townetting of Upper Olga Lake, 1990-1992.

	Tow		Catch by Species					
			Sockeye			Stickleback		
Date	No.	Min.	No.	%	CPUE	No.	%	CPUE
28-Sep-90	3	91	174	30.5	1.9	397	69.5	4.4
8-May-91	3	90	14	1.0	0.2	1,353	99.0	15.0
4-Oct-91	3	94	160	9.8	1.7	1,480	90.2	15.7
21-Sep-92	3	93	275	33.6	3.0	543	66.4	5.8

Table 11.–Biological characteristics of sampled juvenile sockeye salmon by freshwater age caught during townetting surveys of Upper Olga Lake, 1991 and 1992.

	Age 0					Age 1					Age 2				
Date	*n*	%	Length (mm)	Weight (g)	Condition (K)	*n*	%	Length (mm)	Weight (g)	Condition (K)	*n*	%	Length (mm)	Weight (g)	Condition (K)
8-May-91	4	30.8	31	0.3	0.87	2	15.4	73	3.3	0.87	7	53.8	109	10.4	0.79
4-Oct-91	116	72.5	56	1.7	0.85	44	27.5	91	7.0	0.91	-	-	-	-	-
21-Sep-92	213	77.5	67	2.9	0.89	62	22.5	90	8.4	1.03	-	-	-	-	-

JUVENILE SAMPLING IN LOWER OLGA LAKE

A beach seine was used to collect juvenile salmon in the lower lake in July of 1999 and May of 2000. Seine haul catches included adult Dolly Varden *Salvelinus malma*, stickleback *Gasterosteus* spp., and juvenile coho *O. kisutch* and sockeye salmon. Average length of juvenile sockeye salmon in the lower lake in 1999 was 40.6 mm (n=55), while the average length of coho salmon was 46.8 mm (n=52). The same species composition was collected in seine hauls in 2000. The average length of juvenile sockeye salmon on 13 May 2000 was 31.1 mm (n=30), and the average length of coho salmon was 66.4 mm (n=24).

AGE AND GROWTH TRENDS

Freshwater ages: The Upper Station early run historically is comprised of freshwater-age-1 and freshwater-age-2 fish. Over the most recent 15 years of fully recruited early-run returns, freshwater-age-2 fish have made up an average of 62% of the adult returns, and freshwater-age-1 fish have averaged 33% of the total annual adult returns (Figure 6). High (>50%) freshwater-age-1 proportions have occurred 5 times between 1992 and 2006.

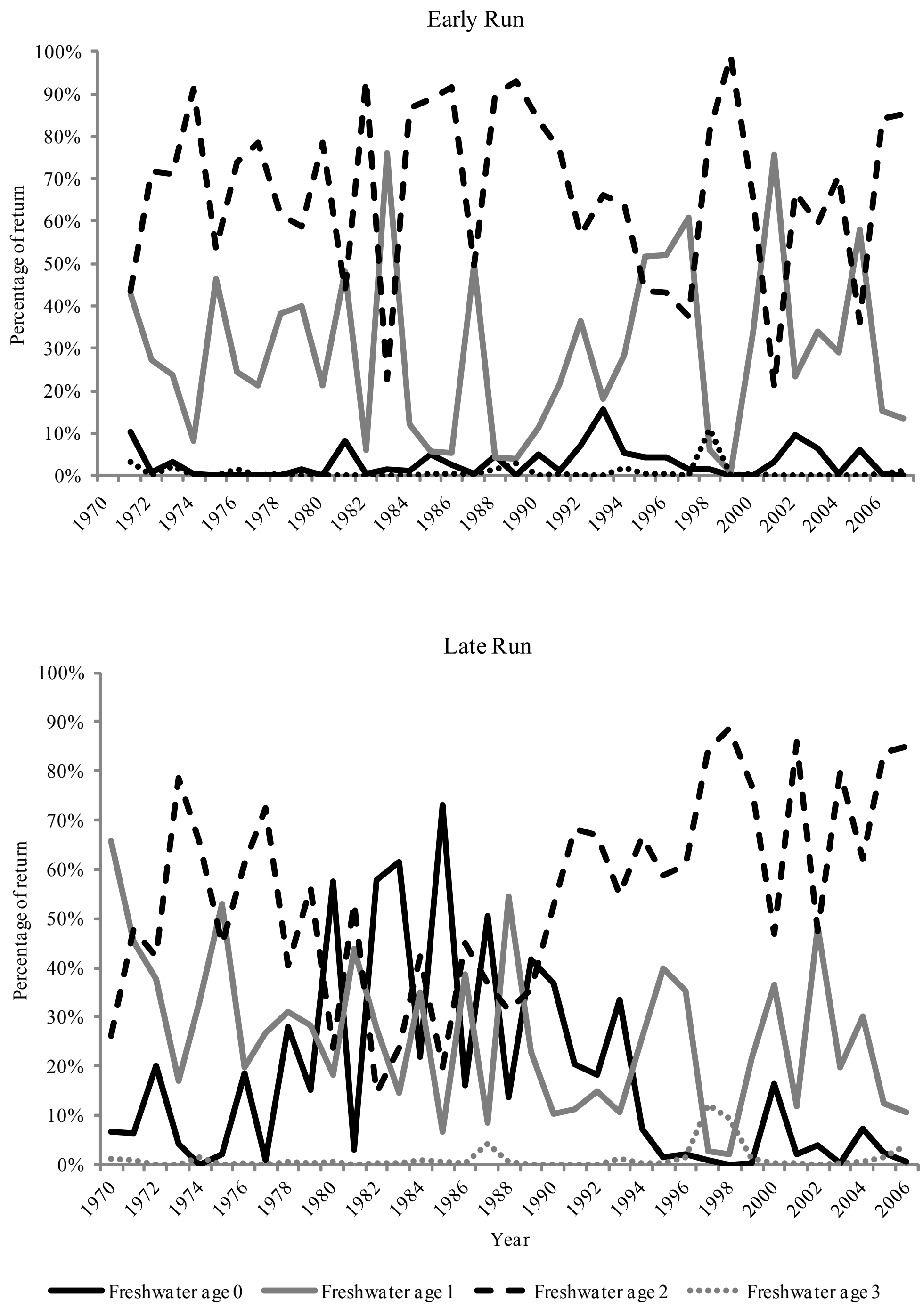

Figure 6.–Historical trends in the proportion of freshwater ages comprising the Upper Station sockeye salmon total returns of fully recruited brood years from 1970 to 2006.

Freshwater-age-2 and freshwater-age-1 fish are generally the predominant freshwater age class of the late run as well; however, between 1978 and 1989 freshwater-age-0 fish were a substantial portion of late-run returns. Since 1993, the proportion of freshwater-age-0 sockeye salmon in adult returns of the late run has decreased significantly, while freshwater age-2 fish have increased as a proportion of the adult returns (Figure 6).

A corresponding decrease in returns of late-run sockeye salmon with this change in age class composition is also apparent. Between 1978 and 1993, freshwater-age-0 sockeye salmon made up 20% or greater of the total late-run adult returns 11 out of 16 years. Coincidentally, some of the greatest levels of early- and late-run escapement occurred during this time period. In contrast, for the 13 fully recruited brood years between 1994 and 2006, freshwater age-0 fish exceeded 10% of the late-run returns only once and average escapement levels of fish were approximately half the average escapement levels between 1978 and 1993.

Saltwater ages: Both early- and late-run Upper Station sockeye salmon typically spend two to three years in the ocean. In late-run returns, ocean-age-2 fish have increased in proportion since the mid 1980s, with an accompanying decrease in ocean-age-3 fish since 1994 (Figure 7).

Figure 7.–Historical trends in the proportion of saltwater ages comprising the Upper Station sockeye salmon total returns of fully recruited brood years from 1970 to 2006.

Although the saltwater-age-1 component of both runs has increased since the 1980s, saltwater-age-1 fish in returns of both runs consistently make up less than 10% of the total return.

No change in average length of adult sockeye salmon over time is apparent in either run (Figure 8). However, the late run generally achieves more growth than the early run relative to age class.

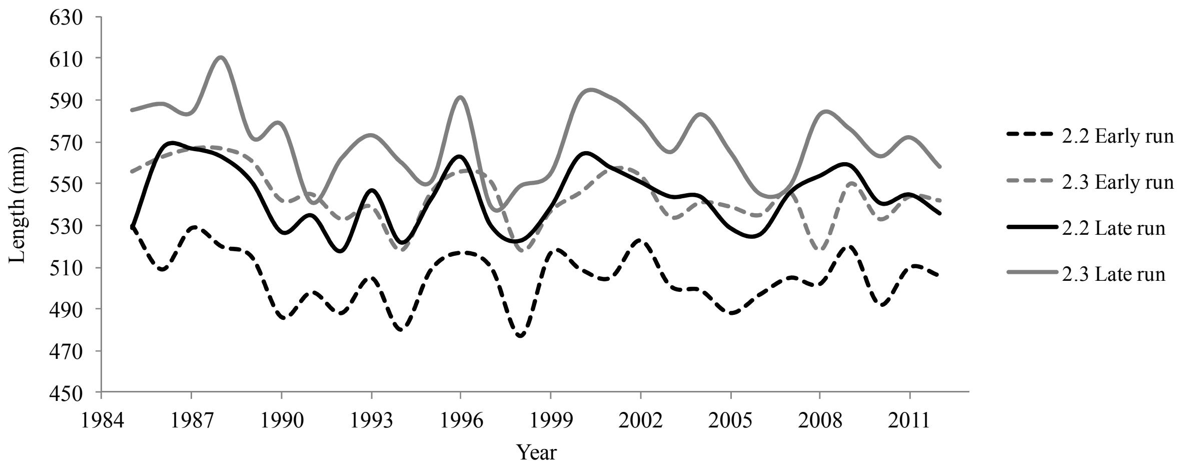

Figure 8.–Average lengths of Upper Station age 2.2 and 2.3 sockeye salmon, escapement samples.

LIMNOLOGY

Water chemistry data have been collected from Upper Olga Lake from 1990 to 1993, 1995, and from 2010 to the present. Zooplankton were sampled from Upper Olga Lake in 1986, 1990, 1991, 1993, 1995, 1999, 2000, and from 2009 to present. Early limnological investigations included two sampling sites on the Upper Olga Lake and one sampling station on Lower Olga Lake (Figure 9). Current (2009 to present) limnological sampling takes place only at Station 1 on Upper Olga Lake. Water chemistry data were also collected from Lower Olga Lake in 1991 and 1993 (Schrof et al. 2000). Temperature, dissolved oxygen and light intensity were collected the same years as zooplankton samples. Samples for a given year were generally collected once a month from May through September.

Limnological data from Lower Olga Lake were collected to varying extents from 1990 to 1993. Generally, Lower Olga Lake is warm, with temperatures ranging between 4 and 16 °C. Dissolved oxygen concentrations were typically high and the entire water column was photosynthetically active. Nutrient concentrations were generally higher than in Upper Olga Lake. Zooplankton production, however, was sparse, falling well below starvation levels (100 mg/m^2; Mazumder and Edmondson 2002)

For Upper Olga Lake the warmest 1-m temperature was 15.2 °C in September 1995 (Table 12). Compared to other years, 1995 and 2000 were the warmest years on average. August was generally the warmest month during the year. The coolest 1-m temperatures occurred in May (3.1 °C in 2009) while 1999 appeared to be an extended and cool spring, with June 1-m water temperatures of 3.6 °C (Table 12). Temperature and dissolved oxygen concentrations measured at 1-m depth were suitable for rearing juvenile sockeye salmon in all years (Groot and Margolis 1991), varying somewhat between years (Table 12).

Temperature depth profiles showed Upper Olga Lake mixes in the spring and stratifies mid summer through the fall. Depth profiles of dissolved oxygen concentrations from October 1992 were unique as they averaged 5.3 mg/L between 19 m and 50 m; dissolved oxygen concentrations at this low level are stressful and can be fatal to fish. This, however, may be more indicative of equipment failure and operator error than actual physical conditions in the lake (S. Schrof Commercial Fisheries Biologist, ADF&G, Kodiak, personal communication).

Solar illuminance data can be used to calculate the depth to which photosynthetic activity occurs (euphotic zone depth; EZD). In Upper Olga Lake, the EZD was greatest in May of 1992 (27.6 m) and lowest in May of 2011 (12.9 m; Table 14). A shallower EZD can occur from algal blooms or increased sediment loads in the water column, both of which would reduce light penetration (Finkle and Ruhl 2012).

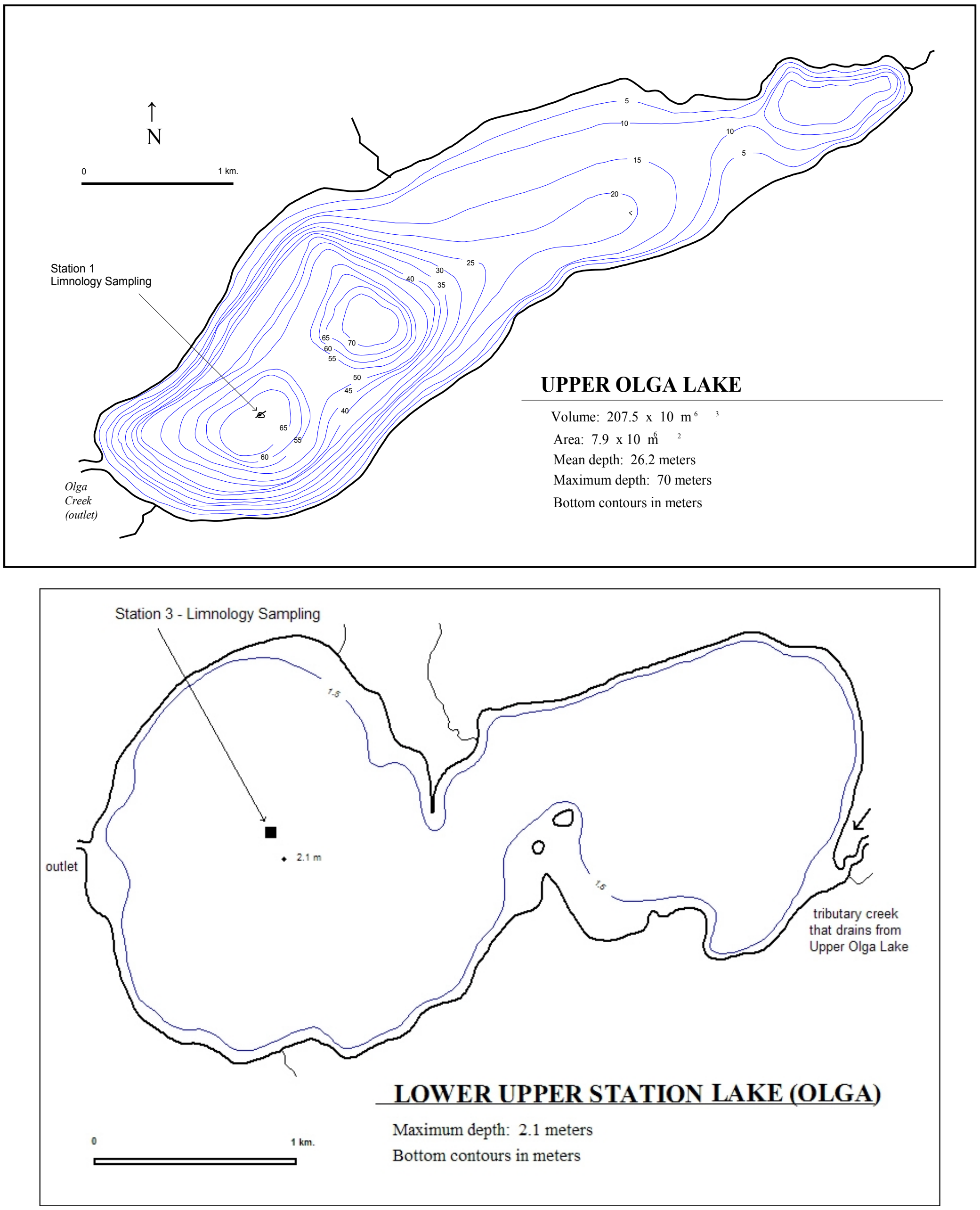

Figure 9.–Bathymetric maps of Upper and Lower Olga lakes.

Table 12.–Historical 1-meter temperature and dissolved oxygen measurements from stations 1 and 2 for Upper Olga Lake.

		Year											
Parameter	Month	1990	1991	1992	1993	1995	1999	2000	2009	2010	2011	2012	2013
Temperature (°C)													
	May	5.3	3.5	3.6	3.5	3.6		3.3	3.1	3.2	3.4	3.4	4.2
	June	8.0		7.3	7.0	10.4	3.6		8.5	6.8	6.0	6.5	6.9
	July	13.0		9.8	10.5		10.4	11.7	14.6	11.4	10.8	11.1	13.3
	August	13.0		14.3	14.0	12.0	12.4	13.1	12.9	12.5	13.3	13.1	13.1
	September			11.0	10.5	15.2			11.9	11.3	11.9	11.3	12.5
	October	10.0		7.7	9.0			10.1					
	Seasonal average	9.5	3.5	8.9	8.6	10.3	8.1	10.4	10.2	9.0	9.1	9.1	10.0
Dissolved oxygen (mg/L)													
	May	12.0	13.0	13.1	13.4	13.2		13.0	13.5	10.4	14.3	13.6	14.4
	June	11.8		12.2	12.1	11.1	12.3		11.5	9.9	13.3	13.6	13.7
	July	10.2		11.6	11.1		10.3	10.3	9.6	10.2	11.7	11.8	10.9
	August	10.5		10.3	10.3	11.2	10.2	9.3	10.4	10.9	10.6	11.2	10.7
	September			11.2	11.2	11.0			9.0	11.0	10.6	11.4	10.5
	October	11.3		11.1	10.8			5.3					
	Seasonal average	11.3	13.0	11.6	11.5	11.6	11.1	9.0	10.8	10.5	12.1	12.3	12.0

Table 13.–Monthly EZD (m) of Upper Olga Lake 1990-2013.

Year	May	June	July	August	Sept	Oct	Seasonal Mean
1990	18.2	15.4	24.0	21.8		16.7	19.2
1991	17.9		20.2			15.9	16.9
1992	27.6	22.0	21.2	21.1	21.2	21.7	22.0
1993	15.8	16.7	17.4	18.5	17.0	17.8	17.4
1995	15.5	18.8		19.5	19.6		18.4
2000	16.5	15.7	17.4	17.4		18.7	15.8
2009	14.1	16.3	18.1	16.0	13.8		15.7
2010	13.3	16.4	16.7	12.6	24.3		16.7
2011	12.9	14.0	19.6	16.3	15.0		15.5
2012	17.1	13.7	17.4	19.2	27.4		19.0
2013	12.2	13.8	18.3	17.9	16.0		15.6

Upper Olga Lake was generally pH neutral in all years ranging from 6.85 in 1991 to 7.67 in 2013 (Table 15). Alkalinity, a measure of a lakes ability to resist changing pH, was generally stable throughout the years sampled, and was comparable to other Kodiak lakes (Table 15; Finkle and Ruhl 2012).

Table 14.–Nutrient and water chemistry data averaged over station and depth by year for Upper Olga Lake.

Parameter	1990	1991	1992	1993	2010	2011	2012	2013
pH	6.88	6.85	6.79	6.78	7.00	7.23	7.50	7.67
Alkalinity (mg/L $CaCO_3$)	8.8	8.8	8.1	9.1	8.7	10.0	9.9	10.0
Calcium (mg/L)	3.5	3.2	3.8	4.7				
Magnesium (mg/L)	0.9	0.5	1.0	4.9				
Iron (µg/L)	28.4	19.1	20.4	16.4				
Total ammonia (µg/L N)	10.4	9.5	5.5	4.4	13.5	10.9	14.3	26.6
Nitrate+ nitrite (µg/L N)	20.0	24.0	21.0	24.0	8.0	10.0	10.0	8.0
Total Kjeldahl nitrogen (µg/L N)	96.1	103.2	106.4	122.5	72.4	229.1	300.1	NA
Total phosphorous (µg/L P)	7.5	8.3	7.3	8.4	7.8	7.4	7.0	6.5
Filterable reactive phosphorous (µg/L P)	2.0	1.7	1.2	1.4	1.0	1.3	0.6	1.2
Total filterable phosphorous (µg/L P)	4.1	3.9	2.9	3.9	2.3	2.5	2.2	2.2
Reactive silicon (µg/L Si)	93.2	98.0	151.7	128.0	66.9	64.0	241.8	178.8
Chlorophyll *a* (µg/L)	1.76	1.98	1.46	3.19	1.80	1.97	2.26	3.59
Phaeophytin (µg/L)	0.98	0.51	1.00	0.92	0.58	0.65	0.22	0.54

A comparison of total nitrogen [TN; TN = TKN + (NO_2^-+NO_3^-)] to total phosphorous (TP) is a simple indicator of aquatic ecosystem health as both are necessary for primary production (Wetzel 1983). TN:TP ratios of less than 10:1 indicate nitrogen limitations (USEPA 2000). Upper Olga Lake TN:TP ratios were generally above this level (Table 14). TP concentrations in Upper Olga Lake, however, have historically been high in comparison to other Kodiak lakes (Finkle and Ruhl 2012).

In addition to nitrogen and phosphorous, silicon is also a vital nutrient for lakes because phytoplankton such as diatoms require silicon for body structure and reproduction (Wetzel 2001). Diatoms are common forage in Kodiak lakes for zooplankton. Silicon concentrations in Upper Olga Lake were comparable to other Kodiak Lakes with strong zooplankton production (Finkle and Ruhl 2012).

Comparisons of chlorophyll-*a* and phaeophytin-*a* concentrations in each year suggest that chlorophyll *a* was adequate for supporting primary consumers (chlorophyll *a* > phaeophytin *a*) such as zooplankton.

The predominant zooplankton collected in Upper Olga Lake was the copepod *Cyclops.* Another copepod, *Epischura*, and the cladocerans *Bosmina* and *Daphnia* were also present to varying extents. Historical zooplankton biomasses have been generally above satiation levels of 1,000 mg/m^2 for juvenile sockeye salmon (Mazumder and Edmondson 2002; Figure 10).

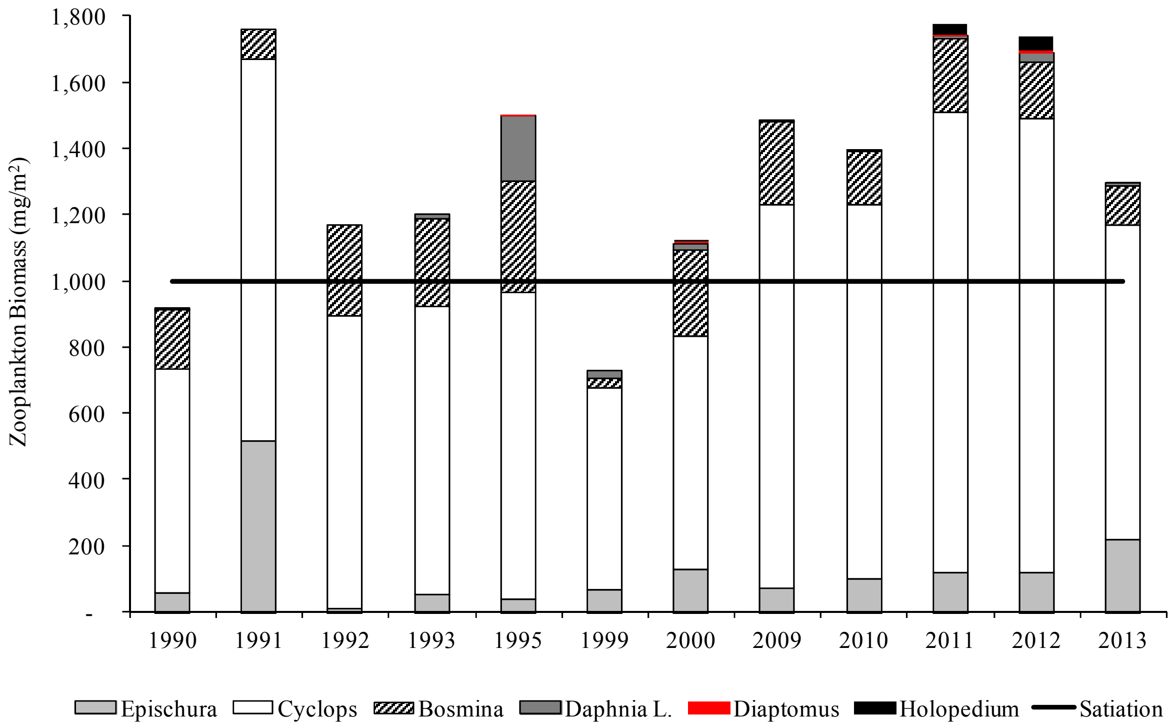

Figure 10.–Seasonal average weighted zooplankton biomass by taxa for Upper Olga Lake, 1990-2012.

Zooplankton are known to be important food sources for juvenile sockeye salmon. Calculating the theoretical grazing pressure of juvenile sockeye salmon using adult escapement and zooplankton biomass data provides another means to investigate freshwater rearing conditions and possible competitive interactions between rearing juveniles. High grazing pressure may be a result of low zooplankton availability or large parent escapements, and may indicate a lack of resources for feeding juvenile salmon. In contrast to growth patterns observed in samples collected in 2013 which suggested poor freshwater growth conditions, the theoretical grazing pressure calculated for 2013 is low, indicating sufficient forage is available for rearing juveniles (Table 15).

Table 15.–Grazing pressure on Upper Olga Lake 1990-2012 using combined total escapement.

Year	Surface Area (km^2)	Combined parent escapement	Spawner Density (No./km^2)	Zooplankton Biomass (kg/km^2)	Grazing Presssure Index (No./kg)
1990	7.9	509,806	64,532	911	70.8
1991	7.9	454,739	57,562	1,759	32.7
1992	7.9	536,047	67,854	1,169	58.0
1993	7.9	418,468	52,971	1,267	41.8
1995	7.9	480,995	60,885	1,390	43.8
1999	7.9	373,141	47,233	718	65.8
2000	7.9	456,553	57,792	525	110.1
2009	7.9	408,512	51,710	1,337	38.7
2010	7.9	358,057	45,324	1,216	37.3
2011	7.9	324,338	41,055	1,289	31.8
2012	7.9	232,545	29,436	1,608	18.3
Average[a]:	7.9	413,927	52,396	1,199	43.7

Table 16.–Upper Olga weighted mean zooplankton density (no/m^2), biomass (mg/m^2), and length (mm) for both egg and non-egg bearing individuals, 1986-2012.

	Epischura			*Cyclops*			*Bosmina*			*Daphnia*		
Year	Density (no/m^2)	Biomass (mg/m^2)	Length (mm)	Density (no/m^2)	Biomass (mg/m^2)	Length (mm)	Density (no/m^2)	Biomass (mg/m^2)	Length (mm)	Density (no/m^2)	Biomass (mg/m^2)	Length (mm)
1986	5,943	6	0.60	161,742	202	0.61	30,990	51	0.42	0	0	
1990	3,318	57	1.39	296,709	676	0.72	85,191	178	0.44	159	1	0.61
1991	77,820	517	1.09	376,849	1,154	0.93	62,799	88	0.40	0	0	
1992	819	11	1.45	410,753	884	0.77	137,208	275	0.45	0	0	
1993	7,095	51	1.19	575,871	873	0.68	173,554	264	0.41	7,418	12	0.68
1995[a]	6,668	37	1.07	490,751	937	0.71	144,871	316	0.48	44,818	100	0.69
1999[b]	12,938	70	1.01	302,495	613	0.74	12,169	25	0.46	10,828	11	0.70
2000[c]	19,515	118	1.11	447,536	667	0.66	129,578	263	0.46	349	0	0.58
2009	7,537	73	1.31	479,830	1,159	0.83	126,592	247	0.46	637	1	0.60
2010	8,599	99	1.39	591,507	1,130	0.74	80,998	164	0.46	1,274	2	0.57
2011	8,386	117	1.27	613,585	1,394	0.78	105,764	220	0.46	5,042	10	0.68
2012	13,004	118	1.25	724,788	1,376	0.73	71,285	170	0.49	9,183	26	0.78

[a] No July sample.

[b] No May or September sample.

[c] No June sample.

ADDITIONAL DATA

The Pacific Decadal Oscillation (PDO) is a long-lived pattern of climate variability. Major changes in marine ecosystems of the northeastern Pacific have been correlated with phase changes in the PDO (Hare and Mantua 2000, Mantua et. al 1997); increased biological productivity has occurred coastally in Alaska yet decreased off the west coast of the contiguous United States during warm eras, while cold PDO eras have had the opposite north-south pattern (Hare and Mantua 2000). Additionally, the PDO has been linked to productivity of Pacific salmon in multiple systems (Mantua et al. 1997). The PDO index switched to a warm regime in 1977 (JISAO 2013), which coincided with the greatest R/S values for the Upper Station late-run. The PDO index, when averaged over six years to encompass the life span of an Upper Station sockeye salmon, is positively correlated with annual returns of the late run between 1970 and 2011 ($p<0.001$, $R^2=0.50$).

When annual PDO index values are summed over the two years covering a 2.2 sockeye salmon's marine life stage, the PDO index accounts for approximately 48% of the variability in total returns ($p<0.01$). This may account for environmental conditions affecting growth, greater food abundance in saltwater, or the population of saltwater predators. The notable decrease in freshwater-age-0 in late run returns at approximately the same time as a phase PDO switch in the 1990s further suggests that climate may influence late-run returns beyond management actions.

SUMMARY

Commercial fisheries management for Alitak Bay sockeye salmon identifies and targets stocks by approximate time period. Past management strategies for overlapping stocks (such as the Upper Station early run and Frazer sockeye salmon) utilized a blended management approach where the upper escapement goals for dominant stocks were not exceeded while still attempting to ensure that at least the lower escapement goals for the non-dominant stocks were achieved. Additionally, adherence to the biological and allocation requirements of all management plans adopted by the Board of Fisheries was required (Dinnocenzo and Jackson 2011). Under the current ABDMP strategy as mandated by the Board of Fisheries, maintaining harvests in order to achieve Frazer escapements may in some years prevent the Upper Station early run from achieving the lower bound of its escapement goal. Restricting fishing to meet Upper Station escapement goals and then conducting mop-up fisheries on Dog Salmon Flats to prevent overescapement have been unpopular and inconvenient for fishermen in the past.

Early-run returns have fluctuated above and below replacement levels the past 40 years. Late-run returns have maintained low replacement levels since the 1990s. Subsequently, early-run and late-run production have declined over time.

Fully recruited brood years from parents of OEG-based escapement started to be realized in 2013. Recent escapements have been some of the lowest on record The OEG, while an important management tool and regulatory requirement, falls below the recommended BEG for achieveing $S_{MSY.}$ If OEG-level escapements and their young are repeatedly and negatively impacted by rearing limitations (such as excetionally cold or wet winters, overcrowded redds, predation, or other factors that can cause juvenile mortality) this may put the Upper Station early-run at risk for depensation. Escapements to the late run have met the lower bound of the escapement goal most years since the ABDMP was put in place, however, only the lower half of the late-run escapement goal has been achieved in the past ten years, and overall production has decreased during this time. Additionally, fish bound for Frazer Lake and both runs of Upper Station sockeye salmon are harvested in other fisheries throughout the KMA. The proportion harvested each year is likely variable, but unknown from year to year.

During the four years of smolt monitoring at the South Olga lakes, the freshwater-age-0 component was greater than any other age class, and freshwater-age-0 fish from those outmigrations comprised more than 50% of their respective adult returns. Typically, there are two drivers behind the outmigration of juvenile sockeye salmon; one being that rearing stressful conditions force fish to leave a system to avoid mortality or two, the fish has achieved adequate growth and condition to be ready to leave (Burgner 1991, Clarke and Hirano 1995, Rice et al. 1994). The dramatic shift in composition of freshwater age classes in adult returns over the past fifteen years suggests that spawning habitat quality or rearing conditions have triggered changes in life history strategies of rearing juvenile sockeye salmon.

Available data indicated freshwater conditions have not changed dramatically from the early 1990s to the present in Upper Olga Lake and it continues to support a healthy zooplankton forage base for rearing fishes. Scale patterns observed in smolt sampled from 2013, however, suggested the freshwater rearing conditions may be poor for freshwater-age-0 and -age-1 sockeye salmon. This trend may be indicative of spawning habitat quality, predation, climatic events, or freshwater conditions isolated to Lower Olga Lake. The shallow nature of Lower Olga Lake has the potential to offer rearing juvenile sockeye salmon a warm environment conducive to growth (Brett et al. 1969) and an aquatic insect forage base. Conversely, Lower Olga Lake also has the potential to hit temperatures metabolically taxing for fry and smolt and possess prey more elusive or of lesser nutritional value than zooplankton (Davis et al. 1998).

A previous study has also suggested that the success of smolt is related to the salinity in the near shore environment (Heifetz et al. 1989). Limited data relating to the nearshore salinity of Olga Bay are available but require further analyses. Correlating smolt population estimates with spring temperatures, winter snowfall and spring precipitation (as a proxy for a spring freshwater lens) might provide further insight into the factors affecting survival of Upper Station sockeye salmon smolt.

RECOMMENDATIONS FOR FURTHER WORK

Sockeye salmon bound for Upper Station are harvested based on Frazer Lake escapement even when Upper Station returns may be weak. Further review and analysis of the production declines of Upper Station might include modeling how targeting different escapement levels at Upper Station might affect early-run depensation, ABD harvests, Frazer Lake escapements, mop-up fisheries, and other management actions. Investigating theoretical management scenarios under different escapement goal regimes (such as a higher OEG level for Upper Station early-run sockeye salmon or targeting the upper end of the late-run BEG) could include comparisons of harvest pressure in relation to catch and escapement of Frazer Lake and Upper Station sockeye salmon. Analysis of these theoretical scenarios might provide guidance to fisheries managers and stakeholders seeking to adjust management practices in the Alitak Bay District with regard to wild and enhanced stocks.

Inseason collection of genetic tissue samples from adult escapement in June could be used as a management tool to help discern the early and late runs, ensuring that each run meets its respective escapement goal. Inseason genetics would also indicate variability in run timing and validate stock composition in the run reconstructions used for forecasting adult returns and escapement goal reviews.

The scale patterns from smolt collected in 2013 showed that freshwater rearing conditions may currently not be ideal for growth in the Olga Lakes watershed. Further study of growth patterns in adult scales would be valuable. Specifically, scale patterns from adult returns compared to escapement and total returns could be a definitive indicator of rearing limitations as evidenced by relationships between growth and survival. Comparisons of adult scale patterns to historical scale measurements of Upper Station adult growth would further indicate the breadth of these changes over time.

Concurrent limnological investigations of Upper and Lower Olga lakes would indicate where and what freshwater rearing limitations occur in the watershed. Temperature loggers deployed in each lake would indicate one aspect of the temporal and spatial disparity in rearing conditions. Nutrient and zooplankton data would serve to indicate if linkages between freshwater trophic levels have failed and affected salmon life history strategies. This information could also be used to help resource managers identify levels of escapement to target relative to inseason zooplankton biomass data.

Information on the diets of juvenile sockeye salmon from throughout the watershed would greatly complement limnological and smolt condition data. Diet data would serve to indicate forage limitations or boons. Prey identification, even at rudimentary levels, would serve to indicate preferred forage and possibly migratory behavior if certain types of forage are not available throughout the watershed.

Changes in rearing conditions in Lower Olga Lake may impact the success of freshwater-age-0 smolt theorized to rear there. Due to the shallow depth of Lower Olga Lake, juvenile sockeye salmon that rear there may succumb to over-winter mortality if the lake freezes or to metabolically taxing conditions during warm springs and summers. Migration between the two lakes or the marine environment and lakes to seek better rearing conditions has not been observed, but could be investigated. Stable isotope chemistry or otolith microchemistry could be used to identify migratory behavior in smolt collected from grab samples throughout the watershed.

Spawning habitat surveys might provide insight to the redd conditions that affect egg and alevin survival. Further work to identify and quantify redd quality and spawner density in Upper Olga Lake would indicate if spawning habitat is poor and if this may affect adult returns.

Continued grab sample collection of juvenile sockeye salmon age, weight, and length data from the vicinity of the Upper Station weir and in each lake would also give some indication as to whether changes in productivity occur in the freshwater or marine portion of the salmon’s life. Ideally, this would include a genetic component to address if each stock reacts similarly to their rearing environment as evidenced by condition and scale growth.

Additionally, investigations of salinity and other conditions in Olga Bay might provide further insight into factors that temper smolt-to-adult survival. Finally, an increased effort to sample returning adult sockeye salmon in the Alitak Bay purse seine commercial catch might allow research staff to build more precise run reconstructions.

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APPENDIX A. HISTORICAL CATCH AND ESCAPEMENT, YIELD, AND RELEVANT COMMERCIAL FISHERY DATA

Appendix A1.–Catch, escapement and total run for Upper Station sockeye salmon, 1976-2013.

	Early Run			Late Run			Combined Runs		
Year	Escapement	Catch	Run	Escapement	Catch	Run	Escapement	Catch	Run
1976	28,567	2,100	30,667	48,650	80,933	129,583	77,217	83,033	160,250
1977	26,380	256	26,636	49,001	66,276	115,277	75,381	66,532	141,913
1978	66,157	14,136	80,293	38,126	161,232	199,358	104,283	175,368	279,651
1979	53,115	11,233	64,348	134,579	262,844	397,423	187,694	274,077	461,771
1980	37,866	5,151	43,017	77,718	127,715	205,433	115,584	132,866	248,450
1981	77,042	22,479	99,521	118,900	179,092	297,992	195,942	201,571	397,513
1982	170,610	30,217	200,827	306,161	345,943	652,104	476,771	376,160	852,931
1983	115,890	27,800	143,690	179,741	361,991	541,732	295,631	389,791	685,422
1984	96,798	19,994	116,792	239,608	328,309	567,917	336,406	348,303	684,709
1985	27,408	6,364	33,772	408,409	522,561	930,970	435,817	528,925	964,742
1986	100,812	113,562	214,374	367,922	1,025,016	1,392,938	468,734	1,138,578	1,607,312
1987	74,747	70,072	144,819	156,274	384,337	540,611	231,021	454,409	685,430
1988	56,724	67,896	124,620	247,647	754,836	1,002,483	304,371	822,732	1,127,103
1989	64,582	59,389	123,971	221,706	485,347	707,053	286,288	544,736	831,024
1990	56,159	106,647	162,806	198,287	512,468	710,755	254,446	619,115	873,561
1991	50,026	119,764	169,790	242,860	514,467	757,327	292,886	634,231	927,117
1992	19,076	22,622	41,698	199,067	219,371	418,438	218,143	241,993	460,136
1993	34,852	51,996	86,848	187,229	258,283	445,512	222,081	310,279	532,360
1994	37,645	57,727	95,372	221,675	235,186	456,861	259,320	292,913	552,233
1995	41,492	170,502	211,994	203,659	383,973	587,632	245,151	554,475	799,626
1996	58,686	154,617	213,303	235,727	666,349	902,076	294,413	820,966	1,115,379
1997	47,655	18,735	66,390	230,793	288,226	519,019	278,448	306,961	585,409
1998	30,713	82,582	113,295	171,214	185,086	356,300	201,927	267,668	469,595
1999	36,521	51,457	87,978	210,016	358,673	568,689	246,537	410,130	656,667
2000	55,761	87,265	143,026	176,783	136,471	313,254	232,544	223,736	456,280
2001	66,795	91,895	158,690	74,408	60,620	135,028	141,203	152,515	293,718
2002	36,801	0	36,801	150,349	9,367	159,716	187,150	9,367	196,517
2003	76,175	24,215	100,390	200,894	211,844	412,738	277,069	236,059	513,128
2004	78,487	190,627	269,114	177,108	336,745	513,853	255,595	527,372	782,967
2005	60,349	95,717	156,066	156,401	124,324	280,725	216,750	220,041	436,791
2006	24,997	7,432	32,429	153,153	62,296	215,449	178,150	69,728	247,878
2007	31,895	5,877	37,772	149,709	44,032	193,741	181,604	49,908	231,512
2008	38,800	60,396	99,196	184,856	237,865	422,721	223,656	298,261	521,917
2009	34,585	46,623	81,208	161,736	187,403	349,139	196,321	234,026	430,347
2010	42,060	13,105	55,164	141,139	63,319	204,458	183,199	76,424	259,622
2011	28,759	22,874	48,361	101,893	68,875	170,768	130,652	91,749	219,129
2012	25,487	34,700	60,187	149,325	64,332	213,657	174,812	99,032	273,844
2013	27,712	29,502	57,214	125573	33656	159,229	153,285	63,158	216,443

Appendix A2.–Upper Station early-run sockeye salmon brood table.

Brood		Age															Total	Return/
Year	Escapement	0.1	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	3.3	2.4	Return	Spawner
1969	22,509	0	317	0	1,406	3,094	281	263	9,979	11,554	0	62	3,516	62	0	0	30,534	1.4
1970	16,168	0	375	188	788	2,889	263	0	1,850	3,269	0	0	1,469	367	0	0	11,458	0.7
1971	32,529	0	0	0	185	1,234	370	0	5,876	15,976	0	0	2,263	0	0	0	25,904	0.8
1972	39,613	0	185	62	1,102	5,693	184	0	3,482	18,977	0	0	8,603	574	208	0	39,070	1.0
1973	26,892	0	0	0	174	522	696	0	3,728	41,006	0	208	7,289	0	0	133	53,756	2.0
1974	35,319	0	0	522	0	26,382	0	0	16,660	38,317	0	0	11,720	133	0	0	93,734	2.7
1975	10,325	0	0	0	0	1,458	208	0	6,393	14,783	0	0	8,738	485	0	0	32,065	3.1
1976	28,567	0	0	0	133	9,722	0	0	10,438	47,090	0	0	27,139	0	0	0	94,522	3.3
1977	26,380	0	0	0	0	32,041	243	0	48,850	94,081	0	0	35,526	634	0	0	211,375	8.0
1978	66,157	0	243	243	1,809	28,948	0	0	32,354	70,735	0	0	19,660	0	37	0	154,029	2.3
1979	53,115	0	0	0	0	4,124	0	0	17,554	65,300	0	46	14,870	38	142	0	102,074	1.9
1980	37,866	0	317	0	2,341	11,937	0	0	4,000	7,165	38	0	7,259	0	25	0	33,082	0.9
1981	77,042	0	0	0	542	2,832	1,498	0	4,370	85,872	0	43	23,861	0	0	0	119,018	1.5
1982	170,610	0	2,472	234	1,006	113,439	781	0	75,684	37,220	0	360	18,131	70	0	0	249,398	1.5
1983	115,890	0	285	1,220	1,181	5,491	1,205	0	11,396	87,555	0	0	41,723	217	0	0	150,273	1.3
1984	96,798	0	109	0	3,443	2,118	66	0	1,792	46,879	0	0	14,103	113	60	0	68,683	0.7
1985	27,408	0	1,476	4	2,865	2,314	22,466	0	6,714	86,949	0	0	42,895	633	64	0	166,380	6.1
1986	100,812	0	35	5,680	449	51,361	936	0	36,048	83,179	60	18	8,248	340	408	0	186,763	1.9
1987	74,747	0	2,134	46	1,022	2,027	3,849	0	726	30,417	27	0	25,242	779	57	0	66,326	0.9
1988	56,724	0	17	0	71	82	852	0	1,607	35,640	210	206	7,282	1,072	0	0	47,038	0.8
1989	64,582	0	450	404	5,823	8,751	6,313	0	5,539	67,810	0	0	34,127	0	0	0	129,217	2.0
1990	56,159	0	1,497	578	0	6,275	3,414	0	19,145	82,269	0	0	6,839	361	6	0	120,384	2.1
1991	50,026	0	407	3,258	20,467	46,391	6,815	0	57,478	131,931	0	0	27,274	0	0	0	294,021	5.9
1992	19,076	52	2,338	223	5,878	5,959	3,583	0	3,435	24,099	0	0	7,268	0	0	0	52,835	2.8
1993	34,852	219	669	605	2,423	5,189	2,741	0	11,812	31,749	0	0	5,168	1,229	0	62	61,866	1.8
1994	37,645	0	229	994	4,887	53,607	1,320	0	7,176	33,104	0	0	17,361	570	0	0	119,248	3.2
1995	41,492	0	185	2,467	5,857	33,691	1,497	360	44,415	44,608	0	492	20,938	689	92	0	155,291	3.7
1996	58,686	0	79	177	2,723	30,487	1,973	0	81,164	51,987	4	25	15,238	281	0	0	184,138	3.1
1997	47,655	0	422	45	0	972	2,438	0	558	11,566	34	0	7,233	795	2,006	0	26,069	0.5
1998	30,713	0	0	6	0	145	6,264	0	418	45,950	0	0	16,490	8	0	0	69,281	2.3
1999	36,521	0	0	2,598	328	27,894	6,080	0	34,497	81,382	0	360	38,405	626	28	0	192,198	5.3

-continued-

Appendix A3.–Page 2 of 2.

Brood Year	Escapement	Age 0.1	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	3.3	2.4	Total Return	Return/ Spawner
2000	55,761	0	780	10,912	7,338	122,434	2,623	69	59,315	40,862	69	121	9,843	139	235	28	254,768	4.6
2001	66,795	0	1,131	1,123	3,856	6,472	5,116	0	4,335	15,475	0	24	13,764	0	0	0	51,298	0.8
2002	36,802	82	532	382	574	1,295	42	36	4,890	2,815	0	0	8,604	0	0	36	19,289	0.5
2003	76,175	0	75	502	88	10,903	3,245	0	9,334	34,250	0	106	13,258	86	0	0	71,846	0.9
2004	78,487	0	191	1,553	6,398	36,836	3,258	0	25,750	32,372	0	0	4,211	0	0	0	110,570	1.4
2005	60,349	0	233	281	0	5,884	3,446	0	3,904	42,706	64	0	9,733	130	0	2	66,385	1.1
2006	24,997	0	0	269	0	1,815	2,367	0	4,513	24,439	5	28	14,943	620	0	4	49,002	2.0
2007	31,895	0	71	26	136	3,578	4,849	0	3,112	28,723	0	16	16,779	0				
2008	38,800	0	0	978	52	10,317	2,056	0	10,703	21,609	5							
2009	34,585	0	108	226	2,336	2,764	2,772											
2010	42,060	0	0	227														
2011	28,759	0																
2012	25,487																	
2013	27,712																	
													10-Year Average (1997-2006):				91,071	1.9

Appendix A4.–Upper Station late-run sockeye salmon brood table.

Brood Year	Escapement	Age 0.1	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	3.3	2.4	Total Return	Return/ Spawner
1970	36,833	0	675	12,594	9,969	81,964	4,431	0	9,161	30,644	632	0	6,171	1,424	0	0	157,663	4.3
1971	95,150	450	5,538	21,045	632	10,109	1,895	0	16,613	40,346	0	0	8,105	901	0	0	105,635	1.1
1972	68,351	3,323	10,425	11,689	17,563	39,397	3,797	0	8,105	58,539	0	0	4,027	0	0	0	156,866	2.3
1973	67,826	1,580	1,424	2,373	1,801	10,807	2,702	0	6,041	77,528	0	0	7,926	0	0	0	112,182	1.7
1974	251,234	0	0	23,416	0	107,734	1,007	0	22,645	294,387	0	0	7,680	7,040	0	0	463,908	1.8
1975	74,456	901	3,021	0	0	61,142	1,132	0	36,479	76,157	0	0	5,228	0	0	0	184,060	2.5
1976	48,650	0	10,190	0	36,479	38,399	2,560	0	11,501	141,154	0	0	10,336	940	0	0	251,559	5.2
1977	49,001	0	640	0	3,137	52,279	1,046	0	66,714	312,897	0	0	9,732	0	0	0	446,444	9.1
1978	38,126	0	82,601	1,046	90,205	134,367	4,698	0	55,146	217,342	0	0	26,755	2,638	0	0	614,798	16.1
1979	134,579	0	31,947	0	63,256	71,366	0	0	103,020	339,950	0	736	10,850	360	280	0	621,765	4.6
1980	77,718	0	124,890	0	56,178	35,951	2,131	0	21,758	55,472	399	0	16,555	965	223	0	314,522	4.0
1981	118,900	0	1,294	0	17,853	157,249	12,280	1,007	149,158	345,506	0	0	14,809	0	0	879	700,035	5.9
1982	306,161	0	644,017	5,129	324,600	364,312	5,029	117	92,824	231,963	0	0	5,168	2,042	0	0	1,675,201	5.5
1983	179,741	4,867	182,514	0	135,177	23,242	1,682	0	53,195	92,799	0	0	30,036	0	1,488	0	525,000	2.9
1984	239,608	3,012	37,733	528	89,721	187,451	5,064	0	21,543	224,033	0	0	23,712	4,642	0	0	597,438	2.5
1985	408,409	2,313	562,757	1,958	309,775	34,924	12,374	0	40,759	179,839	0	578	45,289	6,140	0	0	1,196,706	2.9
1986	367,922	1,449	72,415	1,953	94,380	291,815	5,610	678	116,039	451,917	0	0	17,721	1,579	1,289	6	1,056,851	2.9
1987	156,274	0	68,016	495	113,821	12,899	127	0	17,053	104,995	0	225	27,470	15,072	39	0	360,212	2.3
1988	247,647	0	9,222	216	27,793	76,583	1,000	0	71,330	80,102	177	133	4,037	1,244	0	0	271,836	1.1
1989	221,706	401	169,158	1,125	85,530	83,807	12,864	142	53,928	184,067	308	0	21,693	0	0	0	613,023	2.8
1990	198,287	1,432	56,992	3,904	115,907	27,747	7,728	444	17,591	237,284	0	0	4,315	0	67	0	473,411	2.4
1991	242,860	6,744	51,810	4,858	163,283	73,541	6,484	160	44,507	712,676	31	0	20,546	0	0	0	1,084,640	4.5
1992	199,067	4,913	61,018	1,108	15,733	58,923	12,611	79	6,302	279,349	0	0	7,189	156	192	26	447,599	2.2
1993	187,229	5,186	46,015	5,688	114,817	35,842	45,256	444	10,769	199,820	191	278	27,883	5,350	0	0	497,539	2.7
1994	221,675	1,417	10,206	6,322	23,167	90,488	17,439	44	25,603	293,322	80	0	6,069	968	0	0	475,125	2.1
1995	203,659	233	3,020	3,340	3,349	179,562	24,492	0	13,017	251,855	0	254	14,264	307	247	20	493,960	2.4
1996	235,727	277	1,972	6,536	1,335	35,606	4,057	0	15,478	88,856	121	1	4,856	2,282	0	1,500	162,877	0.7
1997	230,793	0	347	0	916	2,842	11,901	0	1,932	129,206	1,984	130	8,502	17,554	1,942	0	177,256	0.8
1998	171,214	0	0	89	0	2,511	13,979	0	3,281	219,890	25,325	0	13,190	890	0	0	279,155	1.6
1999	210,016	0	279	2,323	672	80,315	15,939	0	20,091	313,886	19	346	40,906	5,360	465	9	480,610	2.3

-continued-

Appendix A5.–Page 2 of 2.

Brood		Age															Total	Return/
Year	Escapement	0.1	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	3.3	2.4	Return	Spawner
2000	176,783	96	34,433	5,197	36,394	122,248	4,045	98	30,388	181,491	0	31	16,677	986	187	165	432,436	2.4
2001	74,408	0	522	215	1,701	5,696	8,310	0	7,078	77,172	0	78	9,900	300	0	0	110,971	1.5
2002	150,349	411	2,421	3,965	7,179	94,543	8,085	0	21,609	95,473	0	0	13,730	0	0	235	247,650	1.6
2003	200,894	43	888	1,667	337	51,307	7,446	0	16,131	256,511	0	357	15,308	548	0	0	350,545	1.7
2004	177,108	669	5,264	1,535	24,845	99,160	7,094	0	29,761	255,957	181	0	5,577	1,457	185	0	431,685	2.4
2005	156,401	139	2,828	2,423	3,067	20,933	20,082	0	6,256	171,458	153	0	8,694	3,150	0	4	239,187	1.5
2006	153,153	0	931	1,561	177	10,327	8,207	0	5,267	126,317	182	74	3,988	6,115	530	0	163,677	1.1
2007	149,709	218	59	787	287	12,235	11,858	0	10,286	140,872	46	276	8,824	241				
2008	184,856	0	0	2,217	349	40,340	7,761	0	10,180	104,940	943							
2009	161,736	376	2,236	1,527	5,784	8,537	16,762											
2010	141,139	58	149	2,064														
2011	101,893	0																
2012	149,325																	
2013	125,573																	
													10-Year Average (1997-2006):				291,317	1.7

Appendix A6.–Returns from brood year escapement by run for Upper Station.

Early Run

Escapement Interval	*n*	Mean Escapement	Return-per-spawner	Yield		
				Mean	Min	Max
10,000-25,000	4	17,642	2.1	36,339	11,458	52,835
25,001-40,000[a]	13	33,727	2.5	80,694	19,289	192,198
40,001-50,000	2	44,574	2.1	90,680	26,069	155,291
50,001-60,000	6	55,079	3.1	167,071	47,038	294,021
60,001-70,000	4	64,471	1.6	100,232	51,298	154,029
70,001-80,000	4	76,613	1.2	91,940	66,326	119,018
80,001-90,000	0					
90,001-120,000	3	104,500	1.3	135,240	68,683	186,763
>120,000	1	170,610	1.5			

[a] 1977 outlier removed; with data point included mean return-per-spawner = 2.9; Yield = 90,747 mean, 19,289 min and 211,375 max

Late Run

Escapement Interval	*n*	Mean Escapement	Return-per-spawner	Yield		
				Mean	Min	Max
30,000-50,000[b]	4	44,828	6	285,222	157,663	446,444
50,001-75,000	4	71,260	2	141,020	110,971	184,060
75,001-100,00	2	86,434	3	210,079	105,635	314,522
100,001-150,000	2	126,740	5	660,900	621,765	700,035
150,001-175,000	5	157,478	2	257,870	163,146	360,212
175,001-200,000	6	186,369	3	467,945	431,685	525,000
200,001-250,000	10	225,459	2	470,731	162,877	1,084,640
250,001-300,000	1	251,234	2	463,908	-	-
300,001-350,000	1	306,161	5	1,675,201	-	-
350,001-400,000	1	367,922	3	1,056,851	-	-
>400,000	1	408,409	3	1,196,706	-	-

[b] 1978 outlier removed; with data point included mean return-per-spawner = 8.7; Yield = 367,616 mean, 157,663 min and 614,798 max

Combined Runs

Escapement Interval	*n*	Mean Escapement	Return-per-spawner	Yield		
				Mean	Min	Max
50,000-100,000	5	77,020	4.1	311,017	165,938	657,819
100,001-150,000	5	119,343	2.9	321,235	131,539	768,827
150,001-200,000	4	187,234	2.7	505,494	212,145	819,053
200,001-250,001	8	226,769	2.3	518,706	305,572	687,204
250,000-300,000	10	278,065	2.2	605,697	203,325	1,378,661
300,001-350,000	2	320,389	1.5	492,498	318,875	666,121
350,001-500,000	3	460,441	3.3	1,510,433	1,243,614	1,924,599

Includes all years (1970-2006)

Appendix A7.–Number of landings by gear type in the Alitak Bay District, 1989 to 2012.

Year	Purse Seine	Set Gillnet
1989	1	87
1990	156	91
1991	185	86
1992	140	79
1993	115	76
1994	111	74
1995	149	75
1996	138	80
1997	91	78
1998	71	77
1999	50	76
2000	58	77
2001	34	77
2002	13	0
2003	22	65
2004	32	71
2005	40	72
2006	24	60
2007	16	58
2008	41	61
2009	50	54
2010	27	67
2011	73	66
2012	57	65

Appendix A8.–Days with harvest greater than zero fish attributed to setnet gear type, 1989 through 2012.

Year	Early Run	Late Run	Combined Runs
1989	27	4	55
1990	32	30	82
1991	27	20	73
1992	20	25	56
1993	29	15	64
1994	27	34	72
1995	34	22	74
1996	31	29	79
1997	16	32	64
1998	26	33	76
1999	9	25	51
2000	25	13	54
2001	28	0	42
2002	0	0	0
2003	6	17	43
2004	34	25	84
2005	33	14	70
2006	2	14	22
2007	7	10	28
2008	29	17	70
2009	26	17	62
2010	8	13	35
2011	18	3	41
2012	18	7	45
1989-2000	25.3	23.5	66.7
2001-2012	17.4	11.4	45.2

APPENDIX B. HISTORICAL SMOLT DATA 1990-1993

Appendix B1.–Weekly estimates by freshwater age class of sockeye salmon outmigrating from South Olga lakes, 1990-1993.

Year	Statistical Week	Dates	Age Class 0	Age Class 1	Age Class 2	Age Class 3	Population Estimate
1990	19	5/03-5/09	0	0	0	0	0
	20	5/10-5/16	0	211	4,607	211	5,031
	21	5/17-5/23	0	3,653	69,281	4,457	77,391
	22	5/24-5/30	0	73,093	1,004,363	30,294	1,107,755
	23	5/31-6/06	0	24,170	78,855	3,469	106,492
	24	6/07-6/13	0	58,354	213,955	11,603	283,912
	25	6/14-6/20	0	29,304	116,251	5,174	150,728
	26	6/21-6/27	2,346	40,350	34,188	490	77,372
	27	6/28-7/04	18,687	16,445	35,401	1,069	71,602
	28	7/05-7/11	2,176,129	6,321	42,214	2,032	2,226,695
	29	7/12-7/18	2,994,481	0	0	0	2,994,481
	30	7/19-7/25	297,022	0	0	0	297,022
	31	7/26-8/01	22,809	0	0	0	22,809
	32	8/02-8/08	0	0	0	0	0
	33	8/09-8/15	0	0	0	0	0
	Total		5,511,474	251,901	1,599,115	58,799	7,421,290
1991	19	5/03-5/09	0	0	0	0	0
	20	5/10-5/16	0	126	47	0	173
	21	5/17-5/23	0	109	93	16	218
	22	5/24-5/30	0	1,630	10,085	1,136	12,849
	23	5/31-6/06	0	5,274	11,833	595	17,702
	24	6/07-6/13	0	7,724	7,693	430	15,846
	25	6/14-6/20	0	159,232	183,386	11,942	354,559
	26	6/21-6/27	0	19,145	19,108	1,082	39,334
	27	6/28-7/04	29	12,032	7,335	190	19,586
	28	7/05-7/11	580,798	5,185	3,682	0	589,665
	29	7/12-7/18	647,285	9,766	2,413	0	659,464
	30	7/19-7/25	538,692	4,226	0	0	542,918
	31	7/26-8/01	167,013	173	0	0	167,186
	32	8/02-8/08	25,606	0	0	0	25,606
	33	8/09-8/15	0	0	0	0	0
	Total		1,959,423	224,622	245,675	15,391	2,445,106
1992	19	5/03-5/09	0	0	210	0	210
	20	5/10-5/16	0	315	1,995	210	2,520
	21	5/17-5/23	0	1,770	126,481	1,095	129,346
	22	5/24-5/30	0	10,366	92,905	0	103,271
	23	5/31-6/06	0	13,983	69,705	121	83,809
	24	6/07-6/13	0	7,403	33,043	0	40,446
	25	6/14-6/20	0	9,284	16,154	19	25,457
	26	6/21-6/27	1,696	14,818	11,663	0	28,176
	27	6/28-7/04	376,527	18,542	10,832	0	405,901
	28	7/05-7/11	611,128	3,760	0	0	614,888
	29	7/12-7/18	369,996	0	0	0	369,996
	30	7/19-7/25	479,082	0	0	0	479,082
	31	7/26-8/01	79,658	0	0	0	79,658
	32	8/02-8/08	29,626	0	0	0	29,626
	33	8/09-8/15	2,530	0	0	0	2,530
	Total		1,950,243	80,241	362,988	1,445	2,394,916
1993	19	5/03-5/09	0	0	0	0	0
	20	5/10-5/16	0	7,814	31,583	1,302	40,700
	21	5/17-5/23	0	23,161	67,470	3,021	93,652
	22	5/24-5/30	0	56,545	124,084	2,618	183,247
	23	5/31-6/06	0	224,994	82,705	1,779	309,478
	24	6/07-6/13	0	71,346	15,716	249	87,312
	25	6/14-6/20	7,323	133,765	27,827	976	169,891
	26	6/21-6/27	159,993	33,801	3,380	0	197,174
	27	6/28-7/04	351,377	8,268	2,067	0	361,712
	28	7/05-7/11	1,136,309	3,256	0	0	1,139,565
	29	7/12-7/18	271,915	0	0	0	271,915
	30	7/19-7/25	264,190	5,392	0	0	269,582
	31	7/26-8/01	210,453	0	0	0	210,453
	32	8/02-8/08	103,688	0	0	0	103,688
	33	8/09-8/15	23,689	0	0	0	23,689
	Total		2,528,937	568,342	354,832	9,945	3,462,058

APPENDIX C. HISTORICAL LIMNOLOGICAL DATA

Appendix C1.–Annual average weighted zooplankton biomass by taxa, 1990-2013.

	Weighted Biomass (mg/m^2)											
Taxa	1990	1991	1992	1993	1995	1999	2000	2009	2010	2011	2012	2013
Epischura	57	517	11	51	36	66	130	73	99	51	78	203
Ovig. Epischura	-	-	-	-	-	-	-	-	-	66	40	14
Diaptomus	-	-	-	-	2	-	5	-	-	2	14	-
Ovig. Diaptomus	-	-	-	-	-	-	-	-	-	-	-	-
Cyclops	676	1,154	884	873	889	545	670	1,032	1,035	1,198	1,214	814
Ovig. Cyclops	-	-	-	-	42	68	34	127	95	196	162	135
Bosmina	178	88	275	264	300	22	244	230	80	34	15	54
Ovig. Bosmina	-	-	-	-	32	2	17	16	82	185	154	68
Daphnia L.	1	-	-	12	133	14	0	1	2	7	9	2
Ovig. Daphnia L.	-	-	-	-	67	12	19	-	-	4	18	4
Holopedium	1	-	-	-	-	-	2	2	1	7	6	1
Ovig. Holopedium	-	-	-	-	-	-	-	2	2	25	38	-
Totals:	913	1,759	1,170	1,201	1,501	729	1,121	1,483	1,397	1,775	1,739	1,295

APPENDIX D. ADF&G MEMORANDUMS RELATED TO ALITAK BAY DISTRICT FISHERIES

ALASKA DEPARTMENT OF FISH AND GAME

DIVISION OF COMMERCIAL FISHERIES

MEMORANDUM

TO:	Patricia A. Nelson Regional Finfish Research Supervisor Commercial Fisheries Division Region IV - Kodiak	DATE: PHONE: FAX:	January 1, 2002 (907) 486-1813 (907) 486-1841
THROUGH:	Steven Honnold Finfish Research Biologist Commercial Fisheries Division Region IV - Kodiak		
FROM:	Nicholas H. Sagalkin Finfish Research Biologist Commercial Fisheries Division Region IV - Kodiak	SUBJECT:	A review of tagging studies pertinent to the Alitak Bay District

The following is an annotated review of studies that contain tagging data applicable to the Alitak Bay District (ABD). Many of the reviewed studies had different objectives, used different techniques, and had different assumptions. This memorandum does not reinterpret results or draw conclusions. In some instances, the conclusions of the original author may be presented.

In many cases the percent of tagged fish recovered is highly influenced by either the small number of fish tagged or the small number of total tagged fish recovered. Several of the tagging studies took place prior to the introduction of the Frazer Lake sockeye salmon stock. There are also instances when tagging studies took place when the Karluk Lake sockeye salmon stock was at historical low levels of production and the Frazer Lake sockeye salmon stock was at historical high levels production. Both the introduction of the Frazer Lake stock and the relative magnitude of other stocks will affect tagging results.

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Rich, W.H. and F.G. Morton. 1929. salmon tagging experiments in Alaska, 1927 and 1928. U.S. Bur. Fisheries, Washington D.C. Bull. 45:1-23.

[as summarized by Tyler et al. 1981] On August 19th and 20th 1928, 700 sockeye salmon were captured, tagged, and released at Broken Point and Uganik Bay. A total of 317 of the 700 tagged fish were recovered. A high proportion of the total number of recovered tagged fish were recovered at the Karluk weir, indicating that a high proportion of fish caught in Uganik Bay were of Karluk Lake origin. Three of the 317 tagged fish were recovered in Alitak Bay and two were recovered in Cook Inlet.

Bower, W.T. 1941. Alaska fishery and fur-seal industries in 1938. U.S. Bur. Fisheries, Washington D.C., Rept for 1939. App. 2. pp.83-111.

[as summarized by Tyler et al. 1981] In 1938, 700 sockeye salmon were captured, tagged, and released at Bun Point and 458 sockeye salmon were captured, tagged, and released at Miller Island. Tagged fish were recovered by commercial fishing vessels and at weirs. Tagged fish recovered at the Upper Station weir averaged 9 days traveling time from being released at Bun Point and 11 days traveling time from Miller Island.

Bevan, D.E. 1959. Tagging experiments in the Kodiak Island area with reference to the estimating of salmon (Oncorhynchus) populations. Ph.D. Thesis, Univ. of Washington, Seattle. 302p.

[as summarized by Tyler et al. 1981] In 1948, 3,925 sockeye salmon were captured from fish traps located in waters along the northwest coast of Kodiak Island and in Alitak Bay. Captured fish were tagged and released in the locations that they were captured. In 1949, 7,277 sockeye salmon were captured, tagged, and released from fish traps along the Northwest coast of the Kodiak Archipelago. The general conclusion was that most commercially caught fish in Kodiak Island waters were from spawning streams near the commercial fisheries with the exception of the northwest coast. The northwest coast was characterized as having a high percentage of non-local stocks in their catches.

Nicholson, L. Fisheries Biologist. [Memorandum to Paul Pedersen, Regional Finfish Biologist, ADF&G]. October 5, 1978.

This was a memorandum from Larry Nicholson describing preliminary results from a 1978 tagging study. In June 1978, 235 sockeye salmon were captured, tagged, and released in waters on the west side of Kodiak Island.

Eighty-five of the 235 tagged sockeye salmon (36.2%) were recovered. Tagged fish were recovered at the Karluk weir (77%), Upper Station weir (8.2%), Frazer Lake fish pass (5.9%), Rocky Point (4.7%), and Chignik Lagoon (3.5%). No tagged fish were recovered at the Red River weir, probably because of high water hindering visibility.

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Nicholson, L. 1978. A summary of all known red salmon (Oncorhynchus nerka) tagging conducted on Kodiak Island, Alaska. Alaska Department of Fish and Game, Commercial Fisheries Division, Kodiak. RUR4K78-06.

This report contains a compilation of tables of data from previous tagging studies conducted in the Kodiak Management Area (Figure 1). There is very little discussion of the results. Due to the volume of data in this report, this memorandum only reviews results relevant to the Cape Alitak District (Table 1). Percentages reported are based on the total number of recoveries and do not reflect differences in catch effort. For example, regardless of the number of fish tagged, if 10 fish were recaptured, each fish represents 10% of the total recoveries.

The highest percentage of tagged fish recovered in the ABD came from Malina Point, San Juan, Miners Point, Halibut Bay, and Cape Alitak tagging locations. The number of tagged fish released at most of these tagging locations was small. The only tagging locations that had high percentages of tagged fish recovered in the ABD and had more than 100 fish tagged and released include Raspberry Strait (1948), Miners Point (1969, 1977), Halibut Bay (1972-1973), and Cape Alitak (all years).

Table 1. Tagging location, total number of recovered and tagged fish per site, and percent recovered in the Alitak Bay District, 1927, 1948, 1949, 1962, 1967, 1970-1973, and 1976-1978.

Tagging Location	% ABD Recov.	Total Recovered[a]	Total Tagged[a]
Malina Point (1948)	0.0%	72	140
Malina Point (1949)	0.3%	669	1641
Malina Point (1977)	62.5%	8	37
Raspberry Strait(1948)	22.3%	86	150
Raspberry Strait(1949)	0.4%	427	976
San Juan, Uganik (1948)	2.2%	229	485
Uganik (1948)	0.0%	63	123
(Uganik 1948)	1.0%	97	240
K.F.C. (1948)	0.0%	40	94
Cape Uganik (1962)	0.0%	22	7
K.F.C. (1949)	1.4%	654	1846
San Juan, Uganik (1949)	0.3%	1474	2814
San Juan, Uganik (1970)	0.0%	11	36
San Juan, Uganik (1971)	0.0%	2	20
San Juan. Uganik (1977)	40.0%	5	37
Broken Point (1927)	0.7%	403	700
Broken Point (1971)	25.0%	4	35
Miners Point (1969)	18.4%	38	202
Miners Point (1970)	0.0%	7	74
Miners Point (1971)	8.7%	23	194
Miners Point (1977)	36.8%	217	553
Uyak Bay (1948)	0.0%	30	61
Chief Cove (1948)	0.0%	58	174
Greenbank (1948)	0.0%	42	68
Greenbank (1971)	33.3%	3	30
Karluk (1948)	0.0%	166	707
Karluk 6/14 (1978)	5.5%	18	237
Karluk 6/26 (1978)	0.0%	1	?
Harvester (1978)	0.0%	0	?
C. Uyak 6/14 (1978)	17.5%	63	?
C. Uyak 6/26 (1978)	0.0%	3	?
Halibut Bay (1971)	12.1%	33	294
Halibut Bay (1972)	53.2%	32	287

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Table 1.–Page 2 of 2.

Tagging Location	% ABD Recov.	Total Recovered[a]	Total Tagged[a]
Halibut Bay (1973)	53.5%	43	173
Old Red River (1976)	5.4%	74	195
Cape Alitak APA13 (1948)	97.2%	183	377
Cape Alitak PAF3 (1948)	96.0%	204	689
Cape Alitak APA15 (1948)	100.0%	56	94
Cape Alitak PAF1 (1948)	100.0%	34	194
Cape Alitak APA 14(1948)	98.3%	118	315
Cape Alitak (1967)	89.5%	192	897
Cape Alitak (1968)	90.8%	153	1170
Cape Alitak (1976)	92.7%	426	1284

[a] Total number of fish tagged is for the site and year. The total number of fish recovered is the total number of fish recovered from that tagging location.

Tyler, R.W., L. Malloy, D. Prokopowich, and K. Manthey. 1981. Migration of sockeye salmon in the Kodiak Archipelago, 1981. Alaska Department of Fish and Game, Commercial Fish Division, Informational Leaflet No. 254. Kodiak.

The increased importance of the Frazer Lake sockeye salmon stock prompted the need for more current information on sockeye salmon migration routes. A total of 3,109 sockeye salmon were captured, tagged, and released at 20 locations along the north, west, and south coastlines of Kodiak Island in June 1981 (Table 2; Figure 2). A total of 1,365 tagged fish (43.9%) were recovered from commercial seine and gillnet fisheries, subsistence fisheries, and fish counting weirs. The number of tagged fish recovered from the seine fishery was relatively small, totaling only 177 fish, while 597 tagged fish were recovered from the gillnet fishery, and 572 tagged fish were recovered from the fish counting weirs. The report speculates that there was deliberate non-reporting of tagged fish by the seine fleet in the Ayakulik sections, which skewed results. Conversely, the recovery of tagged fish by the Alitak-Moser-Olga Bay gillnet fishermen was probably greater than normal because of their wish to emphasize the terminal nature of their fishery on stocks which they believe to be largely of Olga Bay origin. No corrections were made in this report for biases due to varying recovery rates from the fisheries.

The report also indicates that sockeye salmon tagged along the northwest and west coasts showed strong southward movement, and the occurrence of Red River stocks along the northwest coast was considerably higher than reported from tagging studies before 1950.

Over half (57%) of the tagged fish released from tagging locations along the southwest coast of Kodiak Island between Sturgeon Head and Cape Ikolik were recovered in Olga Bay. The percent of the tagged fish recovered in Olga Bay from the Red River area between Bumble Bay and Gold Beach varied from 3% to 73% and averaged 16%; these percentages would have been reduced if seiners in the Red River District had not purposefully retained tags.

Olga Bay stocks migrated principally down the west coast of Kodiak Island. Sockeye salmon stocks from Cook Inlet and Chignik were mixed with Kodiak area stocks primarily at the north end and secondarily at the south end of Kodiak Island. The overall percentage of recovered tagged fish from non-Kodiak Island systems was low, but in some individual experiments in the Marmot Bay to Raspberry Island area the percentage was substantial (27%-73%).

Table 2. Tagging location and percent recoveries in the Alitak Bay District, 1981.

Tagging Location	% ABD Recov.	Total Recovered[a]	Total Tagged[a]
NW Raspberry Island	23.3%	30	120
Raspberry Cape	3.7%	27	147
Noisy Island/Miners Point	48.7%	39	101
Miners Point	14.4%	97	214
Bear Island	83.3%	10	21
Sturgeon Head	53.8%	39	104
Middle Cape	67.4%	46	107
Cape Ikolik	50.0%	46	100
Bumble Cape	15.6%	32	79
W. Old Red River 6/6	50.0%	2	b
W. Old Red River 6/15	37.5%	32	b
S. Old Red River 6/7	18.2%	33	b
S. Old Red River 6/16	73.1%	26	b
N. Red River Marker	3.5%	113	b
S. Red River Marker	5.4%	92	b
Gold Beach	22.2%	9	b
Cape Alitak 6/13	97.9%	243	366
Cape Alitak 6/28	90.2%	164	345
Moser Peninsula	99.5%	204	303

[a] The total number of fish recovered is the total number of fish recovered from that tagging location and the total tagged is the number of fish tagged from that tagging location.

[b] Due to grouping of tagging locations, it is unclear how many tags were released at these individual locations; however, a total of 784 tagged fish were released along this stretch of coastline.

It should be noted that in 1981 the Karluk Lake escapement was low (222,206 early and late combined) and the Frazer Lake escapement was very high (377,716).

The recovery of tagged fish at the Upper Station weir and Frazer Lake fish pass from tagging locations at Cape Alitak demonstrated an average travel time of 9.5 days to the Frazer Lake fish pass and 4.7 days to the Upper Station weir. The report further estimates an average travel time of approximately 3.2 to 3.7 days from the outlet of Dog Salmon Creek to the Frazer Lake fish pass.

Tyler, R.W., L. Malloy, D. Prokopowich, and K. Manthey. 1981. Migration of sockeye salmon in the Kodiak Archipelago, 1981. Alaska Department of Fish and Game, Commercial Fish Division, Finfish Data Report No. 1-85, Kodiak.

This report is identical to Informational Leaflet #254.

Conrad, R.H. Fisheries Biologist. [Memorandum to Richard W. Tyler, Fisheries Professor, Fisheries Research Institute]. September 23, 1983.

This was a memorandum stating Conrad's critique of the 1981 tagging report. Conrad's main point was that interception of non-Kodiak Island stocks was low, particularly in the western and southern coasts south of Uganik Bay to Alitak Bay (~4.3%). However, there was a substantial contribution of non-Kodiak Island sockeye salmon stocks to the northwest Kodiak-southern Afognak district (~17%).

Barrett, B.M. and P.A. Nelson. 1994. Estimated run timing of selected sockeye salmon stocks on the west and east sides of Kodiak Island. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Kodiak. Regional Information Report No. 4K94-6.

This report broadly examines the timing of the primary Kodiak Management Area sockeye salmon runs along with the Upper Cook Inlet sockeye salmon runs along the east and west sides of Kodiak Island. Stocks selected in this analysis had escapement goals of at least 25 thousand fish.

Run timing was based on ten years (1984-1993) of weir data from each system. Local stock run timing at the weir sites was estimated by converting the daily escapement weir count data to percent of the total escapement by day and then averaging the daily values. Run timing estimates of Kodiak sockeye salmon stocks for the west and east sides of Kodiak were determined by adjusting the weir counts back in time to account for travel.

The Upper Station early-run timing peaked during June on the west side, and the late-run peaked in early August.

Ayakulik sockeye salmon run timing on the west side of Kodiak Island was from approximately late May to mid-August. During July, the run was estimated to be just below peak abundance.

The Karluk early and late runs were estimated to be at peak abundance in mid-June and late August, respectively along the west side of Kodiak Island. Both runs were estimated to be relatively weak in July.

The estimated run timing for Akalura sockeye salmon was mainly during late August, while Frazer Lake sockeye salmon were estimated to be at peak abundance in mid-June.

Literature Cited:

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Conrad, R.H. Fisheries Biologist. [Memorandum to Richard W. Tyler, Fisheries Professor, Fisheries Research Institute]. September 23, 1983.

Nicholson, L. Fisheries Biologist. [Memorandum to Paul Pedersen, Regional Finfish Biologist, ADF&G]. October 5, 1978.

Nicholson, L. 1978. A summary of all known red salmon (*Oncorhynchus nerka*) tagging conducted on Kodiak Island, Alaska. Alaska Department of Fish and Game, Commercial Fisheries Division, Kodiak. Regional Unpublished Report No. 4K78-06.

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Tyler, R.W., L. Malloy, D. Prokopowich, and K. Manthey. 1981. Migration of sockeye salmon in the Kodiak Archipelago, 1981. Alaska Department of Fish and Game, Commercial Fish Division, Finfish Data Report No. 1-85, Kodiak.

cc: Brennan, Wadle

ALASKA DEPARTMENT OF FISH AND GAME

DIVISION OF COMMERCIAL FISHERIES

MEMORANDUM

TO:	Patricia A. Nelson Regional Research Supervisor Division of Commercial Fisheries Region IV - Kodiak	DATE: PHONE: FAX:	February 14, 2002 (907) 486-1813 (907) 486-1841
FROM:	Nicholas H. Sagalkin Finfish Research Biologist Division of Commercial Fisheries Region IV - Kodiak	SUBJECT:	Origin of the Upper Station early sockeye salmon run

There has been recent speculation on the origin of the early sockeye salmon *Oncorhynchus nerka* run to the South Olga Lakes (commonly referred to as Upper Station; Figure 1). In particular, some have suggested that this stock developed through straying of sockeye salmon from the introduced Frazer Lake stock. This hypothesis is based on the fact that there was little early fishing time prior to the introduction of sockeye salmon to Frazer Lake (1950s-1970s). There are three ways to determine whether the early Upper Station sockeye salmon run developed from the introduction of Frazer Lake sockeye salmon: (1) examine the timing of the Upper Station runs relative to the Frazer Lake stock; (2) determine the existence and timing of Upper Station escapements prior to and after the introduction of Frazer Lake sockeye salmon; and (3) genetic analysis of sockeye salmon from the two systems. The first two approaches will be addressed in this memorandum and definitively illustrate that the early run is not a result of straying from Frazer Lake. Genetic samples from both of these systems have been collected (Honnold 1997; Burger et al. 2000), and could be analyzed for a subsequent evaluation of these systems.

Timing of the runs

The early sockeye salmon run to Upper Station migrates past the weir beginning in late May and continues through July 15 (Figure 2). The Frazer Lake stock passes the Dog Salmon weir in approximately the same time frame; however, escapement through Dog Salmon peaks in mid to late June, while the early run to Upper Station peaks in early June. Further, the travel time to Upper Station is greater than it is to Dog Salmon, and timing of strays from Frazer Lake through the Upper Station weir would theoretically be later than through the Dog Salmon weir. This is

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not a particularly strong argument because it is conceivable that a stock (i.e., Frazer Lake sockeye salmon) was introduced to Upper Station and then the run timing changed due to the characteristics of the Upper Station system. However, run timing does seem to be an inheritable trait rather than influenced by the environment. For example, Afognak Lake adult returns from sockeye salmon planted into Waterfall and Hidden Lakes had run-timing similar to Afognak Lake escapement (Clevenger et al. 1997). Similar observations have been made for Upper Station brood stock planted into Spiridon Lake, and Saltery Lake brood stock planted into Spiridon Lake (Clevenger et al. 1997; Hall et al. 1998).

Existence of runs

If the early Upper Station sockeye salmon run developed as a result of the Frazer Lake introduction, one would expect Upper Station escapements prior to the Frazer Lake introduction (1950s-1970s) to be unimodal; however, average decadal escapements back to the 1930s demonstrate a bimodal run with similar run timings to the current escapement (Figure 3). The magnitude of the escapements has changed, but these are likely a result of different management objectives and return strength. The return strength of the Upper Station early sockeye salmon run has been shown to be more variable than the late run (Sagalkin *in press*).

Genetics

Genetic samples have been collected from Frazer Lake (Burger et al. 2000) and Upper Station (Honnold 1997) and could be compared in future analyses to determine whether there has been genetic ingression from Frazer Lake into Upper Station.

Literature Cited:

Burger, C.V., K.T. Scribner, W.J. Spearman, C.O. Swanton, and D.E. Campton. 2000. Genetic contribution of three introduced life history forms of sockeye salmon to colonization of Frazer Lake, Alaska. Can. J. Fish. Aquat. Sci. 57:2096-2111.

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